AUTOMATION

OCTOBER 1954
A PENTON PUBLICATION
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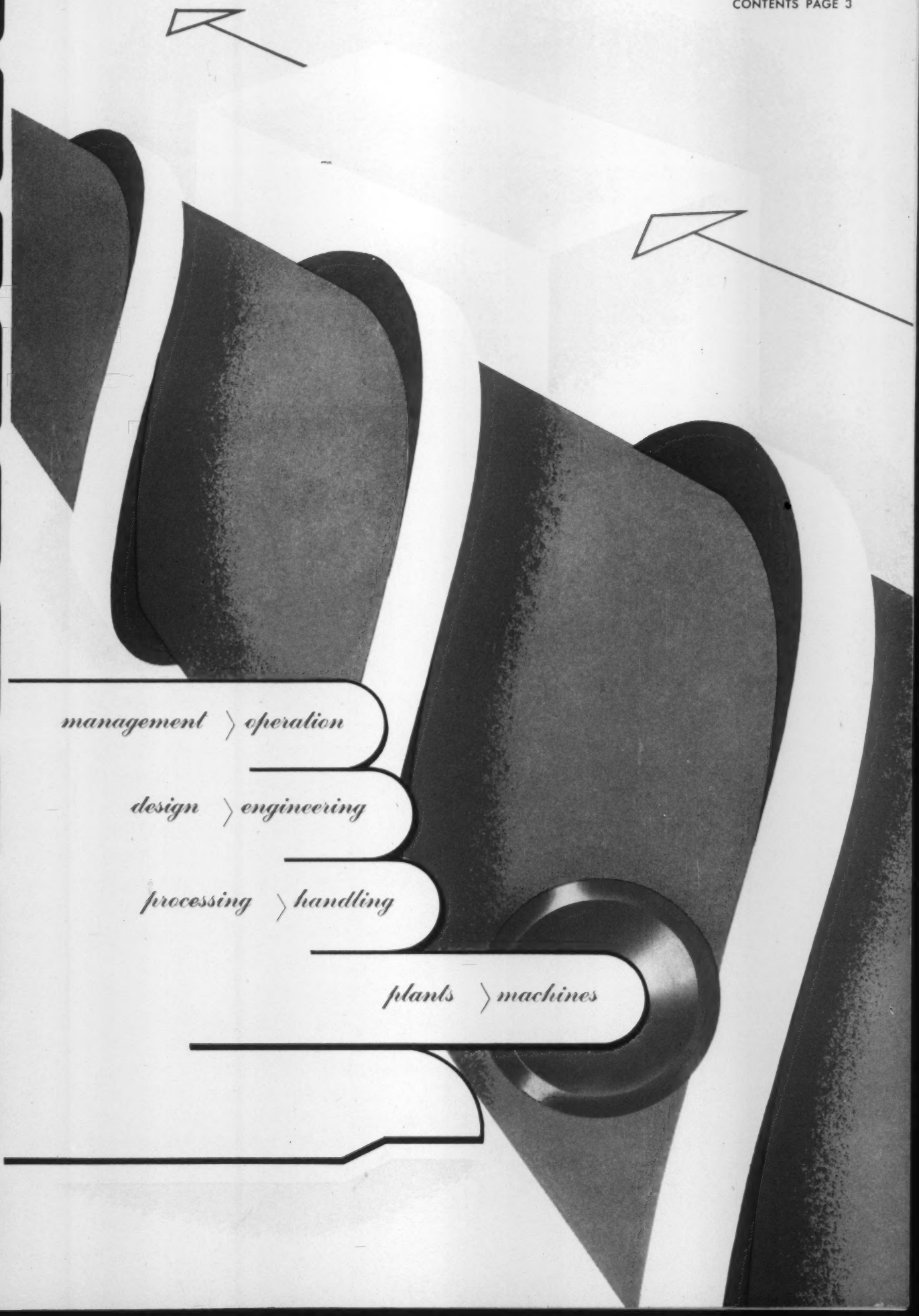

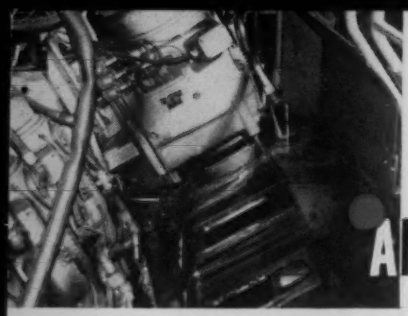

AMAZING "AUTOMATED" DRILL-GRINDER TEAM

DOES THE JOB 22 TIMES FASTER

Machining mounting surfaces on the underside of huge tank hulls required ten separate horizontal boring mill setups. Handling, positioning and working on the heavy, unwieldy hulls created a serious bottleneck in production.

Relying on Wean Equipment's reputation as a leading designer and builder of special machinery for industry this concern gave Wean the green light. Wean Equipment engineers set to work and came up with the first completely automatic adaption of a bank of grinding heads to work on an angular surface.

The machine grinds all surfaces simultaneously with unmatched precision, and completes its job 22 times faster than the old method. According to company officials the machine paid for itself in short order by increasing production, eliminating reworking created by human error, and releasing boring mills to other production work. Result: A second machine to perform a difficult drilling operation on the same hull was ordered from Wean. These are typical examples of Wean Equipment's ability to develop and build practical automation equipment.

If you have a production problem — why not call on Wean Equipment and get results.

Wean

EQUIPMENT CORPORATION

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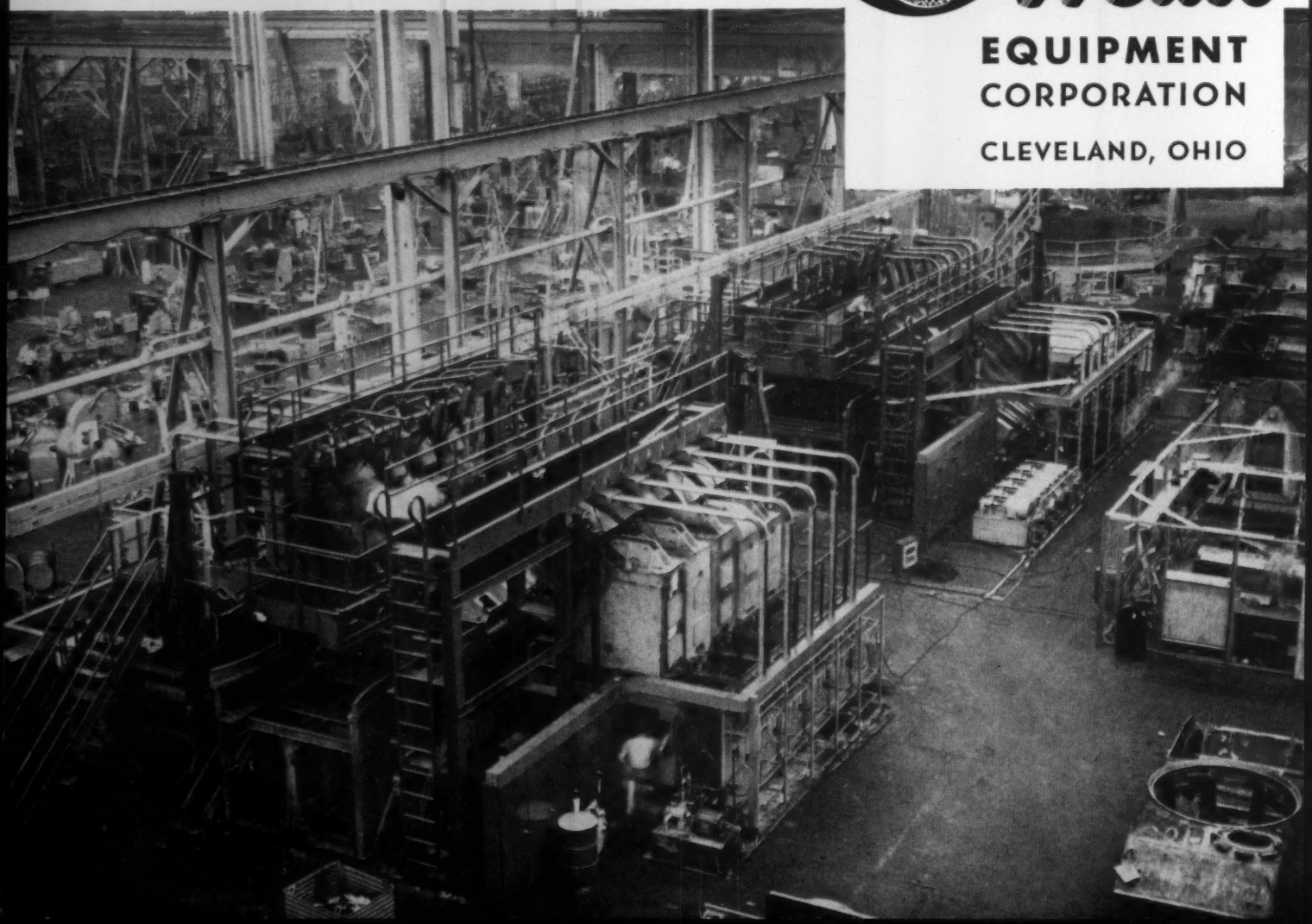

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THE STANDARDIZED PRODUCTION TOOL FOR YOUR AUTOMATION PROGRAM...

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Versatile — Tool and Retool as Required — Type "A" Trans-o-Mator

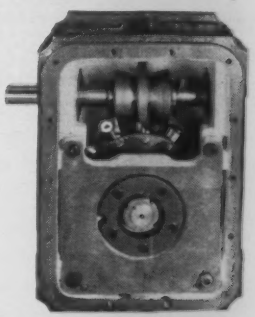
Mechanize Your Manual Operations — Increase Production Rates of Automatic and Semi-Automatic Operations . . .

Increase production, save manpower, improve product quality and cut design time with the new FERGUSON Trans-o-Mator . . . a versatile, standardized, multiple station transfer machine adaptable to many automatic assembly functions in your production operations.

The Trans-o-Mator includes a complete power transmission unit and electrical control panel. Add whatever tooling is required to perform light machining, forming, pressing, assembling and inspection operations and you have a **standardized production implement, tailor-made for your application.**

The Type "A" Trans-o-Mator is designed for versatility of operations in the automotive and other industries where product design changes necessitate retooling. It provides for the widest possible range of assembly operations, inspections, measurements and testings at production rates up to 6,000 pieces per hour. The Type "B" Trans-o-Mator is a high speed unit for the paper converting, electrical manufacturing, packaging and other industries where production rates as high as 20,000 pieces per hour are essential and low product costs are critical.

The success of your Automation Program — the conversion from manual to mechanical operations — depends almost entirely upon such factors as the versatility, simplicity, speed and ease of maintenance of your production machinery . . . upon just those characteristics designed into the FERGUSON Trans-o-Mator . . . so discover how the Trans-o-Mator can be applied to modernize your production lines, how it will save you money . . . **even paying for itself and showing a profit within a year's time!** Send for complete information today.



WITH THE FAMOUS FERGUSON ROLLER GEAR DRIVE FOR HIGH SPEED PRECISION INDEXING

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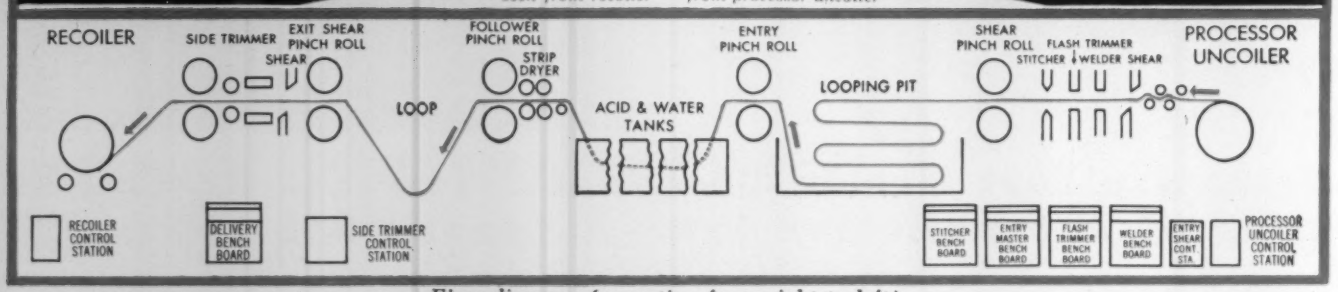
ROLLER GEAR DIVISION, DEPT. BT10 P. O. BOX 191, ST. LOUIS 21, MO.

Manufacturers of the Ferguson Trans-O-Mator, Ferguson Roller Gear Drives, Dial Feed Index Tables, Roll Feeds for Presses, Special Cams, Special Purpose Machinery.

Continuous Pickling Line at Pittsburgh Steel is CLARK Controlled

Exit section seen from recoiler

Entry section seen from processor uncoiler



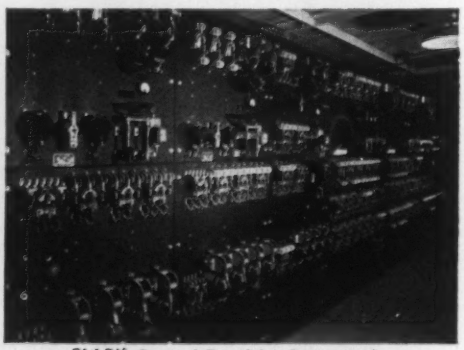
Flow diagram (operation from right to left)

This Wean Engineering Co. continuous pickling line at the Pittsburgh Steel Co.'s Allenport, Pa. mill is powered by 7 DC strip-drive motors and 39 AC auxiliary motors totaling 1409 HP—all efficiently controlled by Clark apparatus.

Designed for a normal operating speed of 500 FPM, this 60 inch combination pickling and side trimming line consists of three sections. The entry section includes the processor uncoiler, shear, welder, flash trimmer, stitcher, and shear pinch roll. The center section includes the entry pinch roll, acid and water tanks, strip dryer and follower pinch roll. The delivery section includes the exit shear pinch roll, shear, side trimmer and recoiler. The control system employs current limit and voltage regulation in all three sections to provide for the most efficient utilization of the available horsepower.

CLARK engineered controls for processing lines are the cumulative result of years of engineering experience. These controls embody the latest circuit designs and devices and are continually being improved to keep pace with production and safety requirements as determined by modern mill practice.

For all types of Processing Lines CLARK engineering "know-how" provides you with dependable, complete control. Consult our nearest District Office for details.



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The CLARK CONTROLLER *Company*

Engineered Electrical Control

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OCTOBER, 1954
Vol. 1—No. 3

AUTOMATION

THE MAGAZINE OF AUTOMATIC OPERATION

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AUTOMATION OUTLOOK

NEEDS FAR-SIGHTED MANAGEMENT

". . . We who work with this fascinating field are convinced that automation is in its infancy. Although progress has been considerable here, rarely comes a problem to which automation cannot be applied to some extent. It is an endeavor which cannot be approached with temerity, and requires an understanding and far-sighted management . . ." — *Clarence Tice, master mechanic, Delco-Remy Div., GMC.* *See page 18.*

STUDIED ENGINEERING APPRAISAL

". . . I want to congratulate you on your (August) editorial. The real reason I am writing this letter is to express my hearty approval of the last two sentences of the second paragraph. These two sentences express what can be the only sane approach if AUTOMATION is to be both a management and engineering magazine.

"In the last two years, since the word 'automation' caught the public fancy, I have been amused by the various dissertations of self-styled 'prophets' who have pawned off fanciful fictions on both management and on the public. This was followed by annoyance when I found that most of them had had no experience in either production or engineering, and finally disgust at many of the predicted conclusions . . ."—*Oswald M. Bundy, manager, product planning, Clark Controller Co.*

JUST AS SURELY

". . . another industry where automation is paramount today is mining—ore, coal, potash, lead, zinc, etc. A mine well ventilated with modern pumps to keep it dry and with every unit driven by electric motors with automatic controls is employing automation just as surely as an industrial plant with automatic handling mechanisms. . ."—*J. W. Corey, president, Reliance Electric & Engineering Co.*

BIGGER DECISIONS

". . . the new automatic factories shall not purge the workman, but coax him none too gently into taking more responsible jobs, making bigger decisions and studying and using his mind as well as his hands. . ."—*Gordon S. Brown, professor, electrical engineering, MIT.*

EXTENDS FAR BEYOND

". . . automation in the automotive industry was originally applied chiefly to machining. Now the concept extends far beyond the engine plants where it gained early success to core making, shell molding, forging, painting, plating, etc. All these developments do not mean that the pushbutton plant is just around the corner or even on the horizon. They do mean that men are being progressively shifted into jobs that demand less muscle and more brain. The unskilled laborer is going to be less and less in demand in the automotive industry, while the market for skilled labor continues to grow apace. . ."—*Automotive Facts, Automobile Manufacturers Assoc.*

SIMPLIFIED FACTORY CONTROL

". . . devices which can convert from digital to analog are likely to be more useful in affording simplified control in the factory. It is possible to type a production schedule on a tape-punching typewriter and produce an analog output by running the tape through a digital to analog converter, creating the means to actuate and control. . ."—*Robert K. Stern, manager, Data Reduction Div., Fisher & Porter Co.* *See page 41.*

AUTOMATION

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Swartz

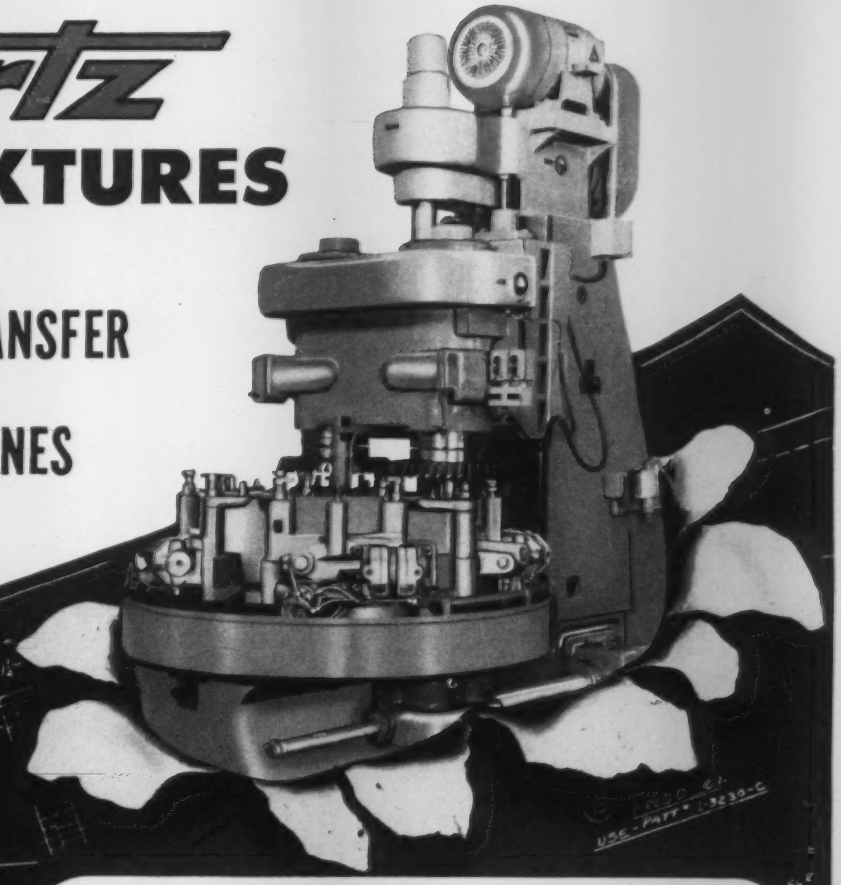
SPECIAL FIXTURES

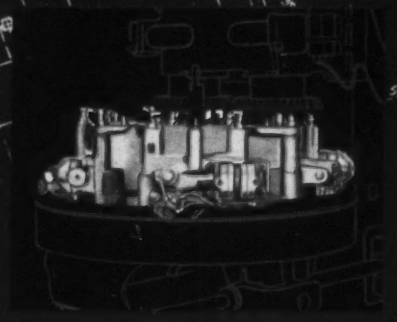
for

AUTOMATIC TRANSFER

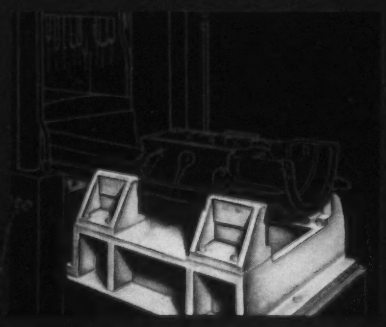
and

INDEX MACHINES





Swartz fixtures were specified for the 4-station Rotary Index Machine shown in the above illustration. The result—dependable, on-the-job fixture performance!



Here is a typical Swartz fixture installation, on a multi-station Transfer Machine. Another example of how Swartz efficiently serves the builders of modern automatic machine tools.

...from PART PRINT to FINISHED FIXTURE!

To both buyer and builder of automatic machine tools, Swartz offers a specialized fixture-building service . . . complete in every detail, from part print to finished product. Swartz fixtures represent the accumulated experience and skill of more than 30 years in this highly specialized field, and the advantages of Swartz service have become increasingly important with the rapid growth of automation.

If you use or build automatic machines, you can profit from Swartz service. Assure yourself of continuous production, with a minimum of costly down-time! *You can*, with dependable Swartz fixtures! They are guaranteed. Call in a Swartz engineer, to discuss your fixture requirements. You'll be glad you did.

Swartz service is presented in a new brochure, "Advancing Automation", and a copy will be mailed on request.

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Division of Jefferson Corporation

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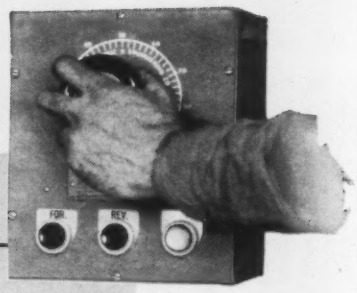
Designers and Builders of: Special Fixtures for Automatic Machine Tools, Pump Jigs, Standard Fixtures, Fixture Locks

More than 30 Years of Specialized Service to the Machine Tool Industry!

Operator's
Control Station



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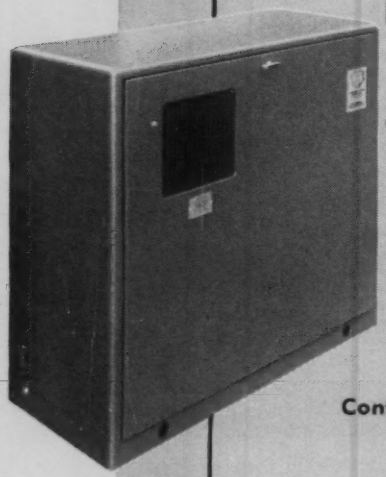
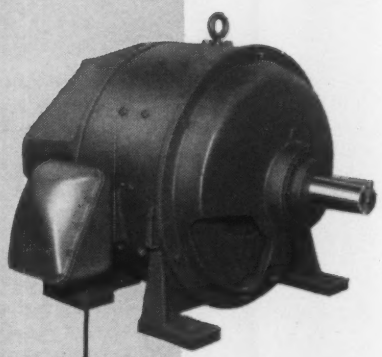
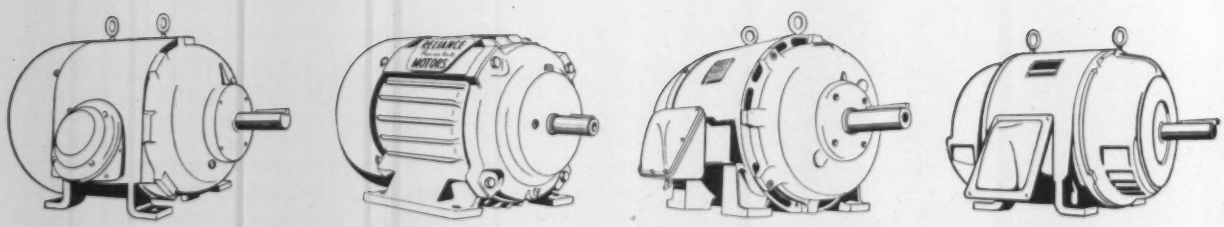
THESE *Tools of Automation* BOOST



Control Unit



Adjustable-Speed
Drive Motor



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RELIANCE Precision-Built MOTORS

RELIANCE V★S DRIVE ®

PRODUCTION EFFICIENCY IN EVERY INDUSTRY

. . . Driving Everything from Machine Tools to Paper Machines

at less cost

If you're looking around for ways to improve your profit ratio—then take a look at these Tools of Automation: They include Reliance motors, adjustable-speed drives, electronic controls, and applied engineering. They've made a lot of companies a lot more competitive.

They are used in the world's largest and most completely automated engine plant. And you will find them delivering outstanding performance on machinery in paper, steel, machine tool, textile—in fact, in every industry.

The nearly 50 years of practical, first-hand experience Reliance has in developing, building and applying the Tools of Automation are available to help you automate a single machine . . . a process . . . or a complete production line. For all the facts, write for our new booklet, "The Tools of Automation."

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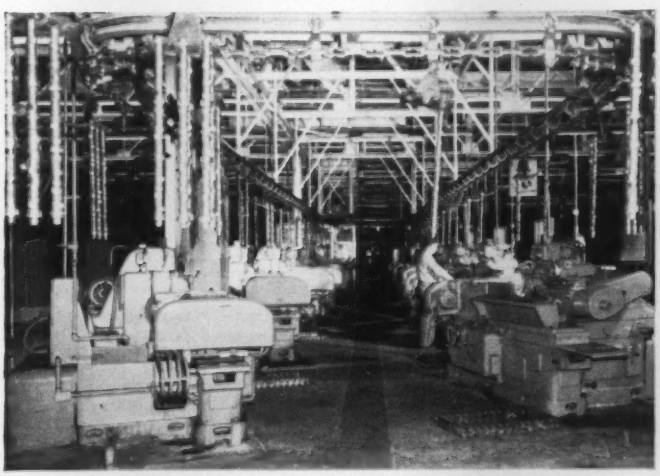
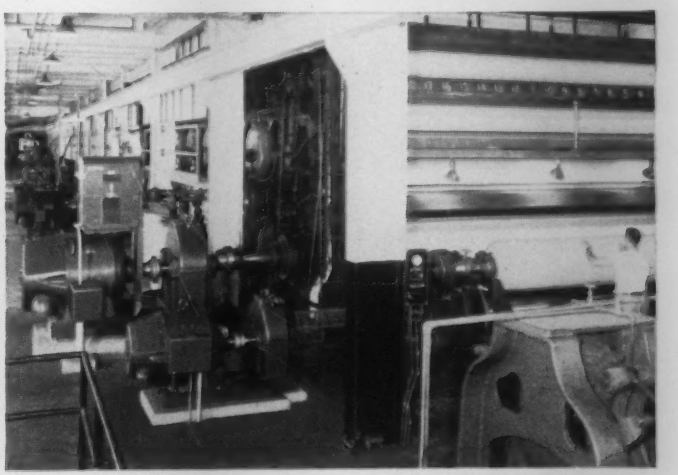


In a camshaft production line, Reliance V★S Drive systems provide stepless, easily adjustable speeds for fast, precision machining. Optimum cutting speeds extend tool life, reduce downtime.



On a high-speed newsprint machine, the Reliance V★S Drive system provides unsurpassed accuracy and dependability, maintaining precise speed relationships and correct draw adjustments between all sections.

AUTOMATION NEWS

Designed for Production

DESIGN SIMPLICITY coupled with use of ceramic material keynotes development of the "stacked tube". Produced for the military by Sylvania Electric Products Inc., the new tube features a ceramic envelope or cap in place of the usual glass bulb. Various components are "stacked" on top of each other in an assembly process, a procedure radically different from conventional methods. Another feature is the use of ceramic spacers instead of mica. These design innovations permit the tube to be put into high mass production. Assembly is actually a simple stacking operation. Sealing is done under a glass dome where the stacked parts are placed, air-evacuated, and the tube envelope sealed over the stack. These stacking, sealing, and evacuating procedures lend themselves to automatic production methods, which make possible large volume and a high degree of uniformity.

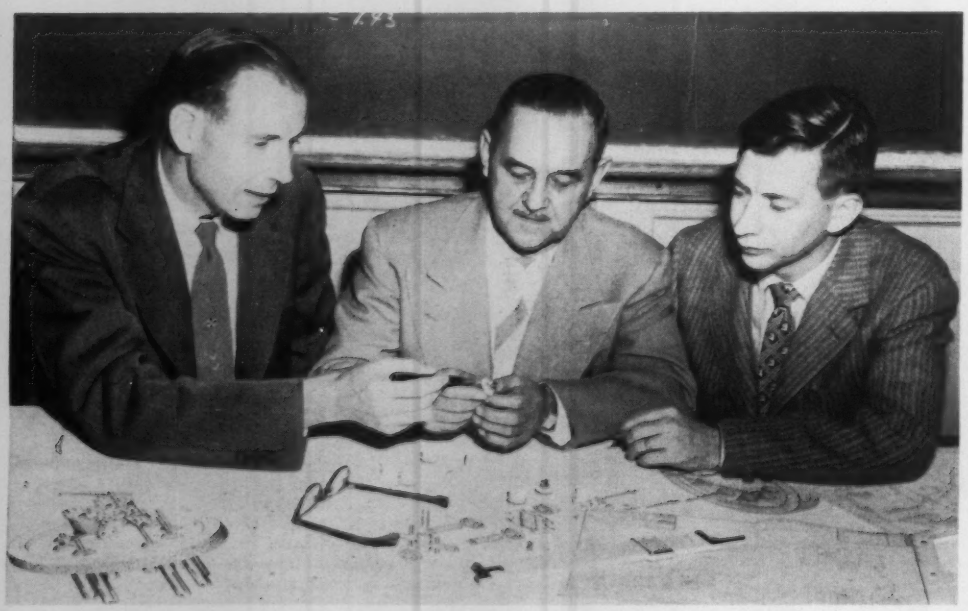
The complete mount of the new tube is assembled on two small pins in order—plate, spacer ceramic, grid, spacer ceramic, cathode, spacer ceramic, etc.—until the top is reached. When the stack is completed, small pins are electrically riveted, giving a compact tight mount assembly.

Ceramic material used for the envelope and stem is aluminum oxide. Sealing the envelope and stem together is a single-step process. No mica is used in the mount, therefore, it can be placed on a ceramic stem and sealed in a ceramic envelope under temperatures of about 950C.

Aside from sealing the tube, this process also provides a high "baking-out" temperature, consequently finished tubes have less gas initially and thus have a longer gas-free life. The new tubes made to date, indicate that when manufactured in this way, they meet physical and electrical objectives in addition to introducing the automatic machine assembly concept to electron tubes.

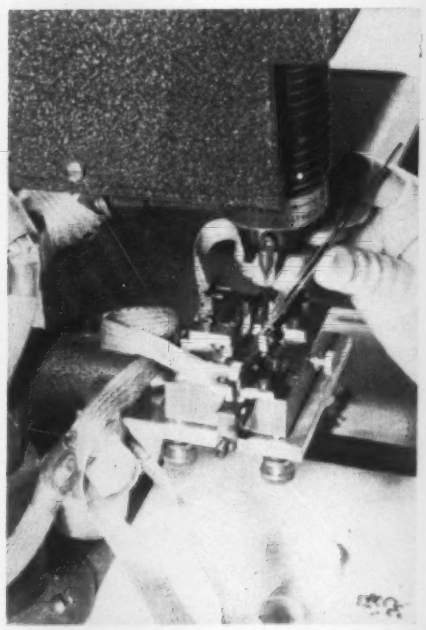
Substituting ceramic spacers contributes to the strength of new tube under extreme operating conditions as mica spacers have a tendency to spall and flake under vibration and shock, causing mechanical failure.

Although an outstanding feature of the new electron tube is the ceramic envelope, the stacked structure lends itself to use of either a glass or ceramic envelope, depending upon the ultimate ap-



NEW CONCEPT, known as the "stacked tube", is the result of several years' study by the Sylvania Research Laboratories. Shown examining the unit (left to right) are Robert N. Palmer, engineer; George T. Gunnell, manager, product development laboratories and William R. Wheeler, engineer. Work has resulted in a development contract with the U.S. Navy's Bureau of Ships and limited quantities are now in production.

plication. The ceramic envelope can be used for severe environmental conditions where glass has not proved feasible, but glass will still be utilized for countless other applications.



TUBE is assembled on two small pins in order—plate, spacer ceramic, grid, spacer ceramic, cathode, spacer ceramic, etc.—until the top is reached. Stack completed, small pins are electrically riveted together in a single operation on the mounting jig shown above.

Electronic Gaging

TO MEASURE overall length and outside diameters of highly polished cylindrical roller bearings, Federal Products Corp. has designed a completely automatic hopper-fed electronic gage which sorts the bearings into 12 classifications of 0.0001-in. each in addition to performing scrap and salvage sorting. The unit tests 6,000 to 8,000 roller bearings per hour.

From a vibrating type hopper, workpieces drop down a vertical feed chute to a platen beneath the mouth of the feed chute. Here a reciprocating feeding finger pushes each workpiece into a slot in a rotating carrier wheel which carries them to the diameter and length gaging stations.

At the gaging stations, the workpiece is pulled between the contacts and its outside diameter and length are found by two electronic gage heads. These signals are transmitted to amplifiers, then to classifiers which "set" the mechanical memory located beneath and keyed to the main carrier wheel.

The rotating carrier wheel next guides the gaged workpiece to the disposal unit. When the workpiece is above the correct disposal chute, the mechanical memory causes a lever to be released, opening the trap door and the workpiece drops into a tote box below.

All timing, measuring and recycling of this electronic gage is controlled by timing cams and microswitches located at the base of the memory unit.

AMA Appointments

FIVE TOP-LEVEL business executives have been appointed to the Manufacturing Planning Council of the American Management Association. Together with the 20 reappointed members of the council, they will serve on a voluntary basis in planning the association's conferences, seminars, and other educational activities in the area of manufacturing management.

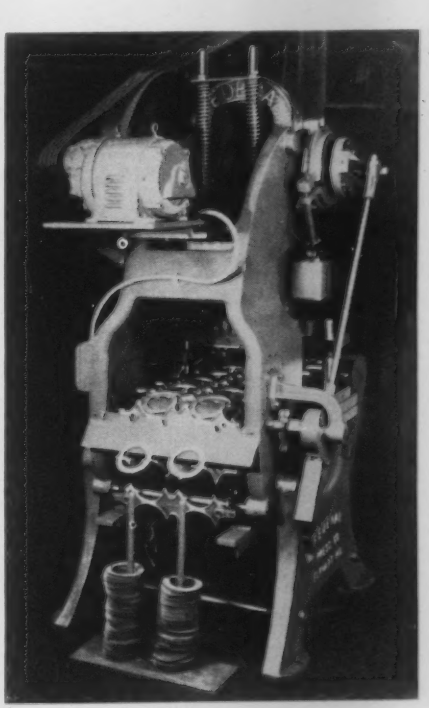
New members are **D. L. Bibby,** vice president, IBM; **Earl S. Havner,** manufacturing vice president, Towle Mfg. Co.; **C. R. Miller,** vice president in charge of production, Eli Lilly; **P. K. Shoemaker,** vice president - manufacturing, H. J. Heinz; and **Maxwell C. Weaver,** president, Randall Co. Chairman of the council is **J. K. Louden,** vice president and assistant to the president, York Corp.

Data Transmission by Radio

FIRST TRANSOCEANIC statistical information to be radioed directly from one punched card to another was sent recently by the U. S. Air Force from Port Lyautey, near Casablanca, Morocco, across 3000 miles to Washington, D. C. During an experimental transmission observed by Army and Navy representatives, information was sent between these two points in both directions at a speed of approximately 1000 characters a minute by an IBM data transceiver, a new machine introduced recently by International Business Machines Corp.

Air Force officials say this method is faster, more accurate and economical than any previous system of transmitting detailed punched-card data between bases. Up-to-the-minute data on men and equipment, supplied in punched card form immediately available for machine processing, will eliminate steps in accounting procedures dealing with the deployment of military forces and the distribution of replacement equipment now maintained at Air Force bases. Use of this new method will help speed the procedures necessary to move replacement parts for planes from depots in the United States to overseas bases.

Information originated at the North African base where a machine operator loaded a data



HIGH-SPEED press featuring a conveyor-type feed, introduced by Federal Press Co., represents a major step toward greater automation in presswork.

Operated by one workman, press shown discharging parts is capable of producing up to 7200 pieces per hour. In developing the first model of the conveyor feed type, company engineers utilized a wide ram and wide bolster plate, permitting a correspondingly wide chain conveyor with 19 pairs of stations (38 in all).

transceiver with IBM cards containing statistical information recorded as punched holes in the cards. As it read the cards, the data transceiver generated electronic impulses, each series of impulses representing a hole in the card. These impulses, sent by radio across the Atlantic, actuated the punching mechanism of the data transceiver in Washington which simultaneously created exact duplicates of the cards placed in the machine at Port Lyautey. The Navy made its radio circuits available for the experimental transmissions.

Installment Plan

MACHINE TOOL users eager for new equipment but lacking the cash purchase price are being offered what is termed "the most flexible and complete financing and leasing plan in the field" by Jones & Lamson Machine Co.

Merchandising programs, worked out by J & L with C.I.T. Corp. industrial financing firm, feature a true lease plan running for periods of up to nine years and an installment financing plan with five-year terms. Also available, in addition to straight cash purchase, was a leasing plan permitting an option to buy. Their standard line of machine tools includes turret lathes, Fay automatic lathes, thread and form grinders, optical comparators and threading dies. Many others are designed for particular jobs.

Four true lease plans are offered, the principal differences being in the annual rental and return charges. With each plan, a 10 per cent deposit is required, to be refunded to the customer upon the fulfillment of the transaction. These plans include no option to purchase, either at a stated time or at a fixed amount, but the user can make an offer at any time to purchase. There is no obligation on the part of the user to buy, nor is there any agreement by J & L to sell. Therefore, these plans are true leases and all rental payments are fully deductible for income tax purposes. Customers get the usual one-year guarantee with a leased machine and can terminate the lease at the end of any year. The lease may run for nine years.

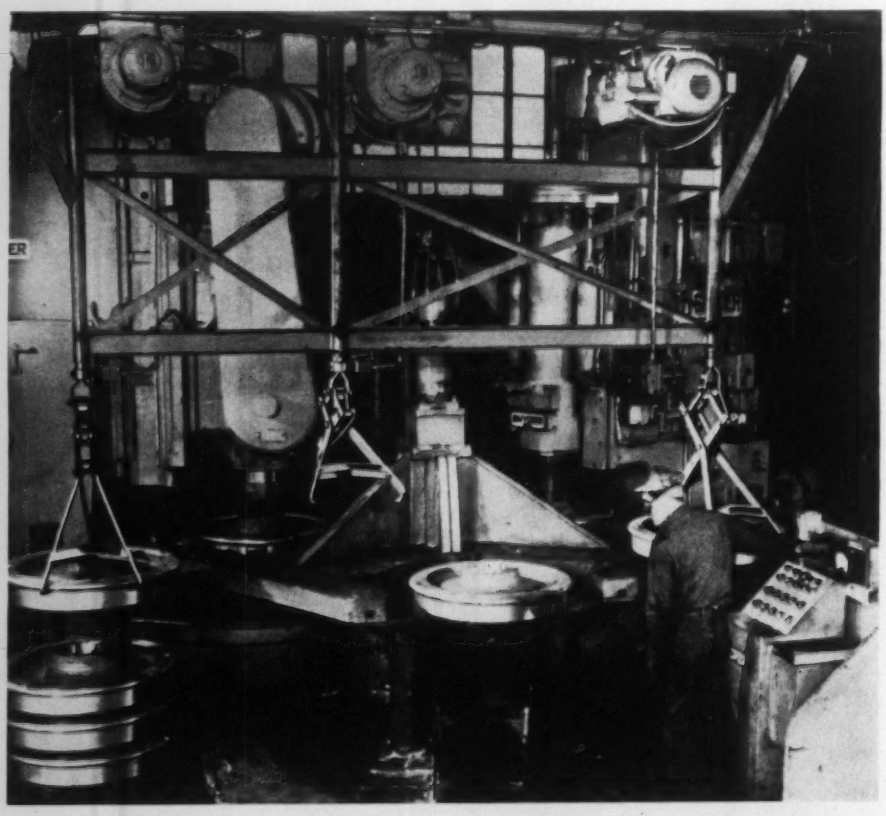
The firm is also offering lease plans giving the customer an option to buy at a stipulated price at the end of any year. Under this arrangement, it is believed that the rental cannot be deducted for income tax purposes.

Automatic Blending

ULTRASONIC ENERGY and electronics have been combined to develop a special monitoring system which automatically blends fuel oil for marine use. Reporting on the first successful field application of this new system, Minneapolis-Honeywell Co. states that the new system is superior to conventional mixing procedures as it accurately blends light and heavy fuel oil to conform with varying burner characteristics in different ships. This accurate blending guarantees high combustion efficiency.

In conventional methods, blending procedures are worked out in advance by mathematical calculation. Chief disadvantage of this so-called "paper blending" is that it fails to take into account varying factors which might throw off measurements. For example, errors in pumps or meters feeding oil into a ship, or possible stratification in the storage tanks, are conditions which might disturb the advance figuring and result in poor blending of the oils which contributes to lower combustion efficiency.

Utilizing this new technique, viscosity of fuel oil is measured by a Ultraviscoson unit (made by Bendix Aviation) and utilizes ultrasonic energy. A probe at-



MACHINING railroad wheel surfaces is now a pushbutton operation with the equipment installed recently at the McKees Rocks Wheel and Axle Div. of U.S. Steel Corp. The device will lift and position a wheel, bore it, face it, and then deliver it to a pile on the floor ready for removal by a fork lift truck. One wheel is bored and another faced while a completed wheel is being removed and another picked up from the floor for boring and facing. Standard 33-inch wheels are completed at the rate of about 27 an hour, under control of one man at the pushbutton panel. The assembly combines a Snyder vertical index boring and facing machine with a specially-designed motor-driven lifting device utilizing three pairs of Heppenstall automatic tongs. The lifting device moves the tongs from side to side to the proper positions, in addition to raising and lowering them.

tached to the instrument is inserted into the line carrying the final blend. Amount of energy absorbed by the fluid from the probe as it oscillates at high frequency indicates the viscosity. Since viscosity varies with temperature change, a compensating unit, also designed by Bendix, is incorporated to adjust the measurement for varying temperatures. As the viscosity varies and is sensed by the probe, information is fed to an electronic control unit which automatically controls the flow of light fuel oil to the mixture by opening or closing a valve.

Etched Circuits for Sale

INCREASED production of large-etched circuits now makes it possible for Bendix Computer to offer these units to other manufacturers. The circuits, used initially for digital computers, have a wide potential throughout the electronics field, including the telephone and television industries.

Etched circuits—electrical wiring in which a thin line of copper is etched onto a flat piece of plastic material—open the way for mass production of circuits by eliminating hand-wiring. In addition, etched circuitry avoids most of the human error encountered in hand-wiring and makes individual circuit testing unnecessary.

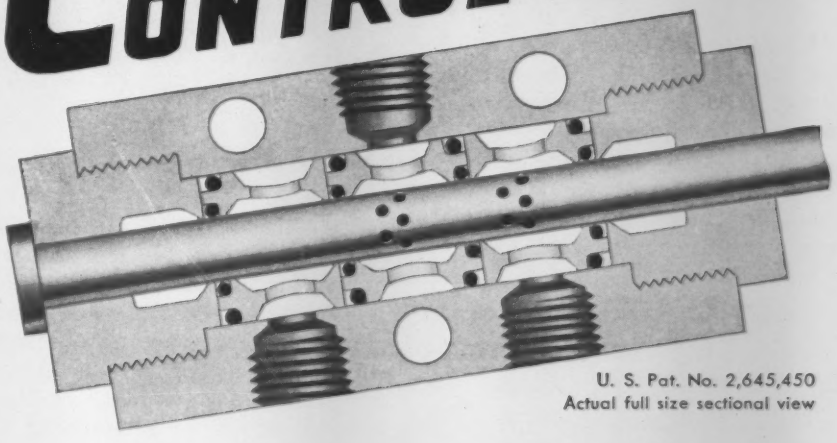
Production methods have been improved and systematized to the point where they are close to an automatic operation. Product uniformity at lower cost is obtained by using photography and silk screen printing for connection and terminal design.

To order etched circuits, customers simply provide Bendix Computer engineers with basic information about the pattern required. Drawings are made from the information and part designations and circuit data are written into the pattern. The layout is then photographed and the pattern is transferred to the circuit base, composed of Bakelite, laminated on each side with a thin layer of copper. The pattern is transferred onto the copper in acid-resisting paint by the silk

NEW, INEXPENSIVE, HIGHLY EFFICIENT

Quick-As-Wink®

CONTROL VALVE

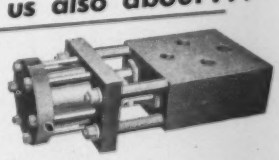


U. S. Pat. No. 2,645,450
Actual full size sectional view

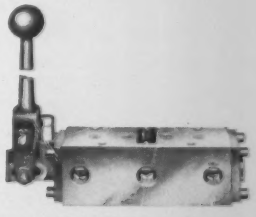
COMBINES greatly simplified construction, positive positioning of all parts, and quick and easy repacking in the field.

• Internal spacers are held firmly and accurately in metal to metal end abutment when the gland nuts are tightened, holding the "O" rings in correct position, without subjecting them to any mechanical pressure. Flow is from the inlet chamber through the hollow, radially ported, stainless steel plunger, and out the connected line. No direct impingement of flow across the packings, greatly prolonging their life. ⅛" or ¼" pipe connections. 2, 3, 4 or 5-way actions. Push-pull; push, spring return; lever; foot; cam; pilot; diaphragm and single and double solenoid designs. Write for Bulletin No. 531 today! *It gives full details.*

Ask us also about . . .



PILOT CYLINDER HYDRAULIC VALVE pressures to 5000 psi. Usually placed close to the work and controlled with an easily operated and conveniently located air valve.



SINGLE PLUNGER AIR VALVE, ¾" to 1½" sizes. Widely used for controlling single and double acting cylinders and as pilots for other valves

Quick-As-Wink

AIR AND HYDRAULIC

Control Valves

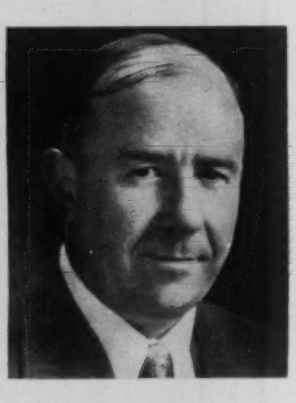
Hand, Foot, Cam, Pilot, Diaphragm and Solenoid Operated

Mfd. by C. B. HUNT & SON, INC., 2073 East Pershing St., Salem, Ohio

screen process and the base is given a ferric chloride bath which dissolves all the copper except the amount under the paint. The paint is then removed leaving the copper etched pattern on the base along with the circuit symbols.

Research Director

CREATION of a new research division, Gray Scientific, to be headed by **Dr. Winfield W. Salisbury** was announced recently by the Remler Co. While Gray Scientific is a division of the electronic manufacturing firm, it will perform only research and development services.



During Dr. Salisbury's long and distinguished career, he has held numerous positions of scientific leadership. During World War II, he was responsible for new developments in radar and radar counter measures for which he received the Presidential Certificate of Merit.

Gray Scientific will be active in research and development work for industry and the armed services and will be devoted principally to the fields of radio, radar and electronic physics.

New Chief

RECENT ANNOUNCEMENT by the American Machine & Foundry Co. discloses that **Frazier O. Stratton** has been named chief engineer of Sterling Engineering Co., a subsidiary of AMF.

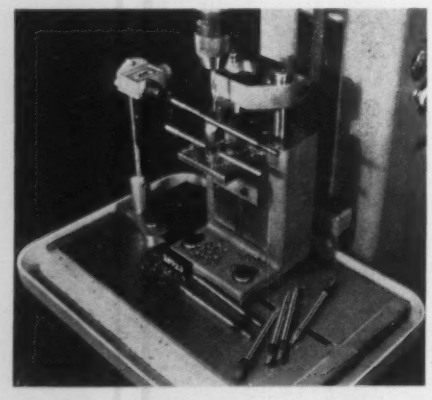
Acquired by American Machine & Foundry Co. in May, 1951, Sterling Engineering Co. manufactures relays and electrical and mechanical equipment.

Prior to joining Sterling Engineering Co. in Sept., 1953 as assistant sales manager, Mr. Stratton was associated for seven years with C. P. Glare Co., Chicago, as sales engineer covering the Middle Atlantic states. He also served as a staff engineer in the sales department of Automatic Electric Co. following five years as chief engineer of the New York Stock Exchange. From 1939 to 1942 he was general manager of service with Thomas A. Edison, Inc., N. Y.

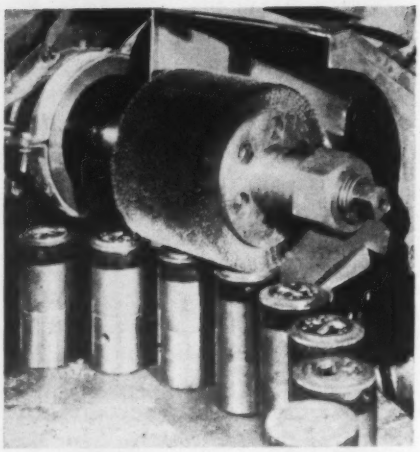
Graphic Information Converter

VALUABLE LINK between graphical information and modern high-speed digital computers, the Benson-Lehner analyzer and reader plus an accompanying digitizer, can quickly read and calibrate multichannel oscillographs or films recorded on either rectangular or curvilinear coordinates, and supply the data automatically to a computer and an electric typewriter simultaneously. Both arithmetic and algebraic corrections, either linear or nonlinear, are applied graphically. For example, logarithms, sine functions, or vector sums can be applied directly while reading traces.

Outputs from the new analyzer-reader are connected directly to any of three types of digital converters, which automatically punch paper tape or business machine cards or record on magnetic tape. This digitized output can be automatically tabulated on an electric typewriter. Another simultaneous operation is possible when the unit is connected to an automatic Benson-Lehner plotter for replotting the data from oscillographs or films to different scales.



SIMPLIFIED precision drilling may be accomplished even by small job shops through use of the universal clamping fixture developed by the Snow Mfg. Co. Shown is a cross-drilling operation. Setup consists of a standard stud and bushing plate tooled to permit insertion of the work piece that contacts a limit switch. When the cycle is completed, the part is ejected by a spring loaded contactor. The work holders vary with the type of part but the base is standard.



TO MEET AN Army contract requirement, Osborn Mfg. Co. eliminated a production bottleneck by using an assembly which will finish 15,000 fuse components per 7-hour day. The problem of removing feather burrs and blending surface junctures after the fuse disks are machined was solved by using power brushes made by Osborn and a Parker automatic machine equipped with 24 rotating spindles. Spindles rotate at approximately 60 rpm and complete one revolution every 25 seconds; spindles do not rotate at the loading station. An air jet lifts the finished part and then blows it into a chute.

Computer Consultant

RAPIDLY INCREASING industrial demand for computers and computer components has prompted two manufacturers, Librascope Inc. and Geo. A. Philbrick Researches Inc. to appoint Askania Regulator Co., a Chicago concern, as their Midwestern representative.

Librascope produces computer components and specializes in the custom design of computing systems. Geo. A. Philbrick Researches Inc. manufactures a line of electronic analog computers.

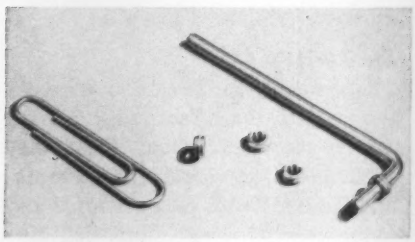
Dr. Richard Skulski has joined Askania Regulator Co. as a computer consulting engineer to direct that company's activities in behalf

of the two computer firms. During the past five years, Dr. Skulski has been an instructor in mechanical engineering and a research engineer at Armour Research Foundation.

New Project Engineer

DESIGNERS of machinery and processes for rubber and plastics, Hale and Kullgren, Inc. announced recently the appointment of **Merrill T. Ham** as a project engineer.

Mr. Ham was formerly associated with Monsanto Chemical Co. and Hollingsworth and Whitney Co. He served with the Army Engineers after graduating from the University of Maine. In his new position, Ham will specialize in new plant layouts and automation in connection with the company's work.



MULTIPLE SPLINE socket set screw, designed for specific tasks in guided missile assembly has been developed by the Bristol Co. The socket is broached all the way through, enabling the screw to be wrenched from either end with equal ease. This feature also helps promote rapid assembly; the screws can be fed from an automatic feed line with either end up and still be handled by automatic assembly methods.

Alloy Replaces Silver Contacts

THROUGH UTILIZATION of copper-tungsten contacts, General Electric Co. has doubled the life of the contactor used in an oil-immersed starter. Tests proved that fine silver contactors were subject to excessive wear when applied to oil-immersed starters. Thus, silver contacts were replaced with Gibsiloy UW-8 manufactured by Gibson Electric Co.

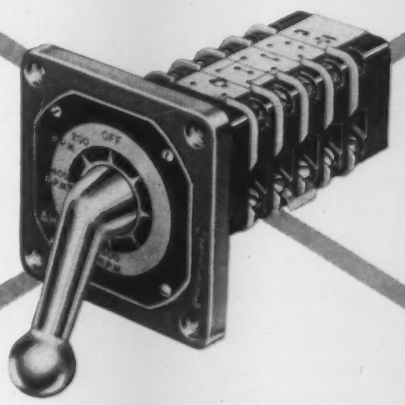
These new contacts withstand severe and confined arcing during starter operation with little erosion. Resistance has been suffici-

AN ADVANCE IN AUTOMATION!

ARROW AH HART

ARROW-HART
PUSH-PULL
SELECTOR SWITCH

PROVIDES *MULTIPLE* ADVANTAGES THROUGH SINGLE POINT CONTROL



Arrow-Hart doesn't *follow* the trend to automation . . . *Arrow-Hart leads the way!* Proof of this is the "PPS" PUSH-PULL SELECTOR SWITCH CONTROL that provides a single point of control for multiple-operation machines . . . *up to 16 positions available from one compact control station.* The operator can start or stop any of the machine operations . . . and move from any position on the dial to any other position without activating any of the intervening circuits.

- *ACTS IN PLACE OF MANY PILOT DEVICES* . . . such as push buttons, switches, etc.
- *PERMITS USE OF FEWER MAGNETIC CONTROLS* . . . such as starters, contactors and relays.
- *SAVES MONEY, SPACE AND TIME* . . . since there are fewer controls to buy, install and maintain.
- *PROTECTS MACHINE AND OPERATOR* . . . because the position of the single handle always indicates the last operation performed and (except where required by special conditions) one operation must be stopped before another can be started.

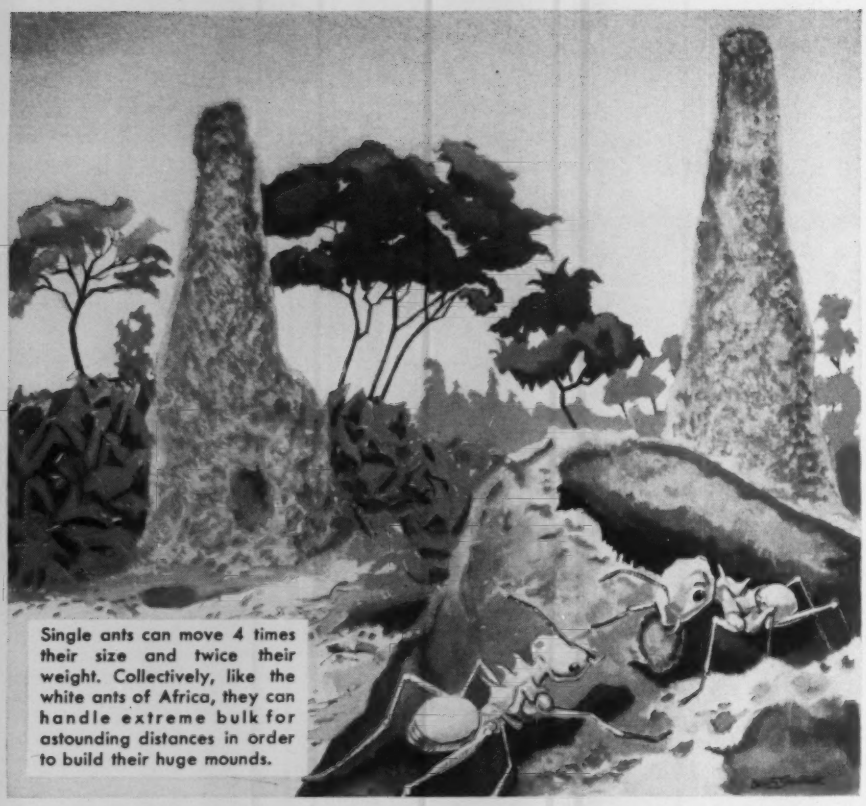
The "PPS" SWITCH CONTROL is another excellent example of Arrow-Hart *Advanced Design* Electrical Controls that are *available now* and that will be standard equipment in the "automatic factories" of the future.

WRITE FOR COMPLETE ENGINEERING DATA TODAY

ARROW AH HART

THE ARROW-HART & HEGEMAN ELECTRIC CO.
103 HAWTHORN ST., HARTFORD 6, CONN.

Quality Motor Controls • Wiring Devices
Enclosed Switches • Appliance Switches



Single ants can move 4 times their size and twice their weight. Collectively, like the white ants of Africa, they can handle extreme bulk for astounding distances in order to build their huge mounds.

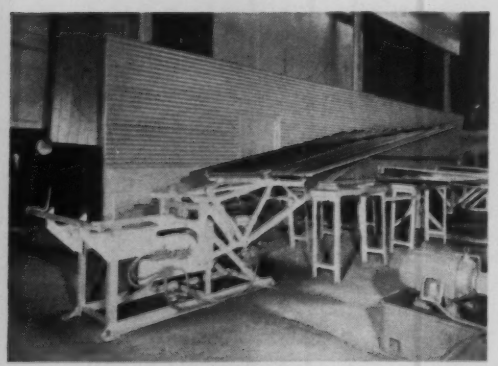
EXPERTS IN AUTOMATION

It was not too long ago, as time is measured, that man was restricted in what he could move from one place to another by the limits of his individual brawn. But now, through science, he need simply to push a button to handle the most cumbersome object.

Automation, the science of automatic material handling, transferring and precision flow control, is the specialty of *Allied*. They have designed and fabricated some of the most unique machines used by industry today.

If you have a problem in material handling peculiar to your business, consult *Allied*. Their staff of automation experts will make a study of your situation and provide a practical and cost saving solution for it.

PIONEERS IN AUTOMATION... the design and fabrication of fully automatic material handling systems



This Allied installation maneuvers large steel doors through a production cycle—every phase automatic, all movements synchronized. Magnets hold the door while being up-ended and automatically hung on to a moving conveyor for completing fabrication.

For further information ask for Allied Catalog 953

ALLIED AUTOMATION DIVISION
ALLIED STEEL and CONVEYORS, INC.
17377 Healy Avenue, Detroit 12, Michigan

ently low to assure low temperature rise. Applications include use of electrical contacts for tap changers and oil-immersed apparatus.

MEETINGS AND EVENTS

Oct. 1-2—

Standards Engineers Society. Third annual meeting consisting of four technical sessions to be held Chalfonte-Haddon Hall, Atlantic City, N. J. Additional information may be obtained from M. S. Gokhale, P. O. Box 281, Camden 1, N. J.

Oct. 11-12—

Conference on Mechanisms. Second conference on mechanisms for automatic machinery to be held Purdue University, Lafayette, Ind. Additional information may be obtained from the Editors, AUTOMATION, Penton Bldg., Cleveland 13, O.

Oct. 11-13—

American Management Association. Fall manufacturing conference to be held Plaza Hotel, New York. Additional information may be obtained from association headquarters, 330 West 42nd St., New York 36, N. Y.

Oct. 11-15—

American Institute of Electrical Engineers. Fall general meeting to be held at the Morrison Hotel, Chicago, Ill. Additional information may be obtained from H. H. Henline; Secretary, 36 West 46th St., New York 36, N. Y.

Oct. 13-16—

National Industrial Conference Board. Third annual conference on Atomic Energy in Industry to be held Hotel Commodore, New York. Additional information may be obtained by writing Marion Lipson, 247 Park Ave., New York 17, N. Y.

Oct. 14-15—

National Conference on Industrial Hydraulics. Tenth annual conference to be held Sheraton Hotel, Chicago, Ill. Additional information may be obtained from C. E. Schmitz, conference director, 35 West 33rd St., Chicago 16, Ill.

Oct. 14-Nov. 18—

Symposium on Automation. Sponsored by local sections Institute of Radio Engineers and American Institute of Electrical Engineers; meetings to be held each Thursday evening at 7:30 p.m. Additional information may be obtained from S. E. Moore, 1317 Spruce St., Philadelphia 7, Pa.

Oct. 20-22—

American Management Association. Annual office management conference to be held Hotel Astor, New York, N. Y. Additional information may be obtained from association headquarters, 330 West 42nd St., New York 36, N. Y.

Oct. 25-27—

American Institute of Electrical Engineers. Machine Tool Conference to be held Hotel Statler, Detroit, Mich. Additional information may be obtained from Kurt Tech, Chairman of AIEE, Subcommittee on Machine Tools, 33 West 39th St., New York 18, N. Y.

Oct. 25-27—

Packaging Institute. Annual meeting to be held Hotel Roosevelt, New York, N. Y. Additional information may be obtained from Lawrence V. Burton, 342 Madison Ave., New York 17, N. Y.

Nov. 1-5—

National Metal Congress and Exposition. International Amphitheatre, Chicago. Additional information may be obtained from W. H. Eisenman, 7301 Euclid Ave., Cleveland 3, Ohio.

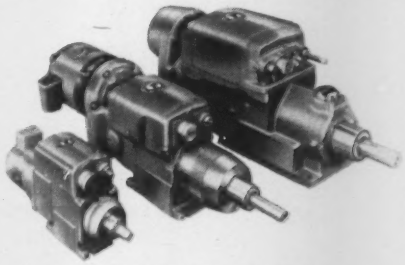
Nov. 11-12—

AMA Office Management Seminar. First of three meetings to be held AMA headquarters. Additional information may be obtained from association offices, 330 W. 42nd St., New York 36, N. Y.

Nov. 15-17—

American Standards Association. Fifth national standardization conference to be held Hotel Roosevelt, New York. Additional information may be obtained from association headquarters, 70 E. 45th St., New York, N. Y.

Want a special-purpose machine that PAYS FOR ITSELF fast?



Special purpose machines built around low-cost Rockwell Air-Hydraulic Drill Units *pay for themselves* by cutting production costs on drilling, tapping, counterboring and similar operations. And it's *easy* for you to find out how you can take big cuts out of your costs through new methods.

HERE'S ALL YOU DO...

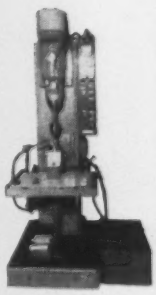
STEP 1. SEND THE COUPON below for this Drill Unit Catalog containing actual case histories plus detailed data on the Rockwell Drill Unit and what it can do for you. Included with it will be an Engineering Application Data Sheet for your use.

STEP 2. FILL OUT THE DATA SHEET and send it to Rockwell. It will take only a few minutes of your time to give the data necessary for us to make an intelligent analysis of your production problem.

STEP 3. ROCKWELL WILL SEND YOU A METHODS STUDY—without obligation—including preliminary suggestions, accurate cost and savings estimates, and results that may be expected. You'll also receive the name of your nearest Rockwell Drill Unit Dealer.

STEP 4. CALL YOUR AUTHORIZED ROCKWELL DRILL UNIT DEALER. He employs methods engineers qualified to go into your plant and prepare—with your men—a complete justification report on your proposed application.

STEP 5. DEALER DEMONSTRATES DRILL UNIT IN YOUR PLANT. You actually see in action the exclusive Rockwell Drill Unit advantages that can give you better production *at far lower cost.*



STEP 6. ROCKWELL TESTS YOUR PROPOSED TOOLING PLAN. If you are considering an untried tooling set-up, your dealer can arrange to have it tested in Rockwell laboratories where specially metered Drill Units determine torque, thrust, and cutting speed requirements for your specific application.

Air-Hydraulic **DRILL UNITS**

Another Product by **Rockwell**

Send the Coupon Today...

it can be the beginning of big savings for years to come!

Drill Unit Division, Rockwell Manufacturing Company
316K North Lexington Avenue, Pittsburgh 8, Pa.

☐ Please send Rockwell Drill Unit catalog, with application Data Sheet.

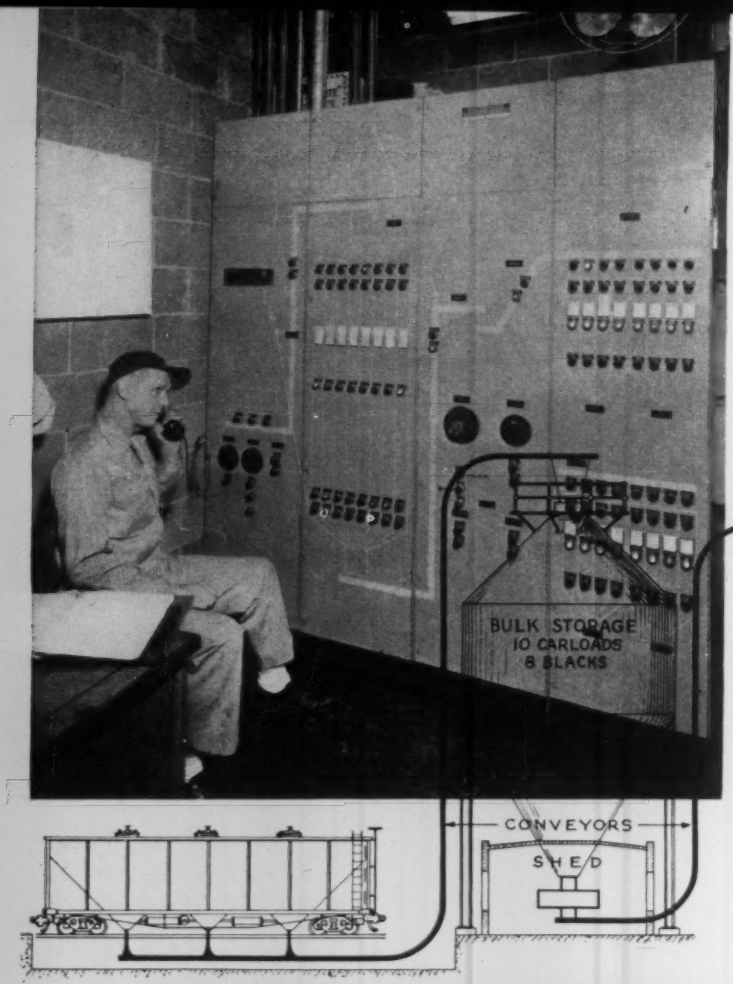
Name_____ Title_____

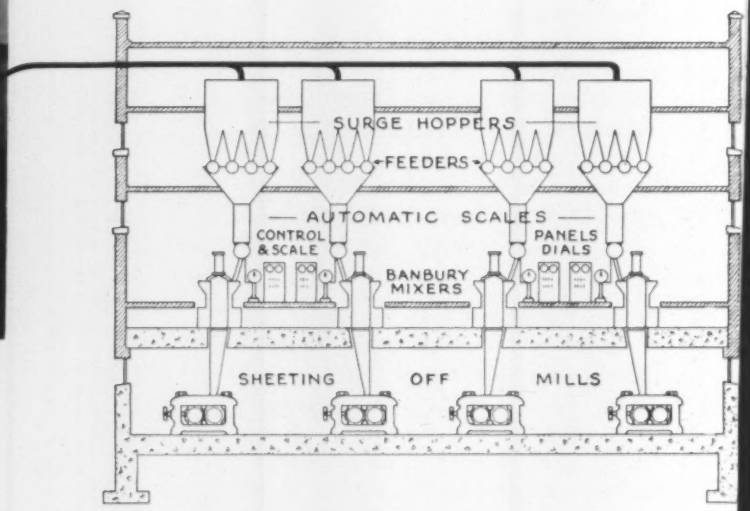
Company_____

Address_____

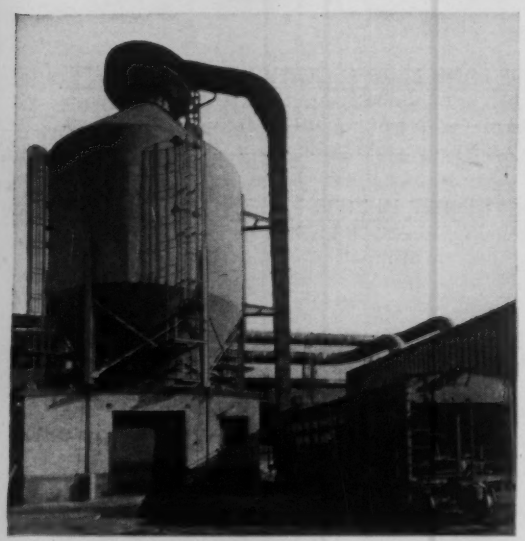
City_____ County_____ State_____

AUTOMATIC
bulk handling plant
FOR CARBON BLACK

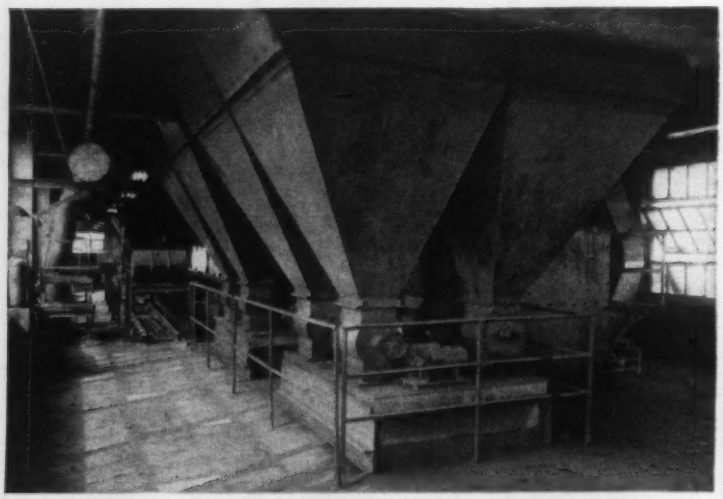




Operator can route black from railroad car to any one of eight sections in the bulk storage, then from storage to any one of 16 surge hoppers over four Banbury Mixers. Such equipment can be adapted to any type of resins or ingredients where bulk shipments are desirable.



This illustrates conveyor lift between a railroad car and 8 compartment bulk storage.



Surge hoppers over Banbury Mixers. An operator at the Banbury Mixer sets his weigh scale for the exact amount of black required. He also sets the control and puts into operation a feeder that serves to select the type of black needed.

Carbon black moves from railroad cars to mixers without a human hand touching the material. Automatic controls elevate, convey and weigh the black into mixers. Their versatile system stores several kinds and types of black in carload lots . . . thus you have a variety of blacks available at each mixer. Push buttons on master control board route each black to its proper distribution.

For a complete plant; a specialized process; an engineering service or individual machines for rubber or plastic, write Hale and Kullgren, P. O. Box 1231, Akron, Ohio.

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MANUFACTURED BY

THE AETNA-STANDARD ENGINEERING CO., PITTSBURGH, PA.

PLANTS IN WARREN, OHIO · ELLWOOD CITY, PA.

Power for Progress

Seventy-five years ago Edison achieved success in his search for a practical electric lamp. Thus did he open the doors to what we could rightly call the "age of light." His succeeding inventions in generators, circuits, devices and distribution systems began the era of electricity—light, power and progress.

Light has illumined the path to greater knowledge and enlightenment. And from such humble beginnings, electricity has become the fundamental building block of power and progress. With Edison's development of the efficient generator for lighting, the electric motor became a practical tool of industry.

Today, as we move rapidly into the age of automation, electricity furnishing light, power and control holds a key position. Few of today's automatic marvels would be practical without electrical power and control. Even electronics, which grew from Edison's first lamp experiments with his so-called Edison Effect, has today reached new heights where the amazing possibilities of tomorrow defy prediction.

In 1850, the average American worked 70 hours a week. Today he works an average of 41 hours a week. In 1850, he produced about 27 cents worth of goods an hour. Today he produces about $1.40 worth in dollars of the same purchasing power. In other words, the average American a century later can produce five times as much in an hour as he did in 1850.

With the rapid expansion of automation, output will continue to increase, helping maintain ever higher standards of living. And, wherever automation is brought into industrial and commercial areas to make possible these increases in output, power consumption generally rises. It will continue to increase.

No, electricity has not yet reached its full potential. As automation takes over the work of brute labor, helps create more goods with less work and more leisure, more and more men will be able to study and explore the vast new horizons which are opening to the eyes of men. Tremendous as it appears today, the role of electricity in the tomorrows will be far greater.

Light for freedom—power for progress.

EDITOR

PUSHBUTTON MANUFACTURING

In manufacturing, automation is in its infancy. But progress has been made. In this article a fascinating panorama of today's automatic manufacture is revealed

By CLARENCE TICE
Master Mechanic, Delco-Remy Div.
General Motors Corp.
Anderson, Indiana

NO—we don't have it, but perhaps we are on our way. The goal of absolute automation in *any* manufacturing plant is certainly a long way off, and the day of simple pushbutton operation has certainly not yet been reached. We, at Delco-Remy, realize this and recognize that such steps as have been taken have hardly scratched the surface of this challenging problem. Automation in the field of manufacturing is a term not clearly definable and is so diversified in its application that it can be used to cover an almost unlimited field of endeavor. A recently published definition describes the term automation as follows: "In essence it is the automatic processing of raw materials into finished products, and is merely the logical conclusion to the evolutionary developments that harnessed the earth's power to the machine". This is what is said about it, so let's take a look at what we have done about it.

In the field of automotive accessory equipment in which we manufacture, competition is keen. Products are greatly diversified but for the most part on such production levels an extensive tooling program can be undertaken. During the evolution of machine development here, automation has found its way into all phases from the processing of the raw materials to the packaging of the finished product.

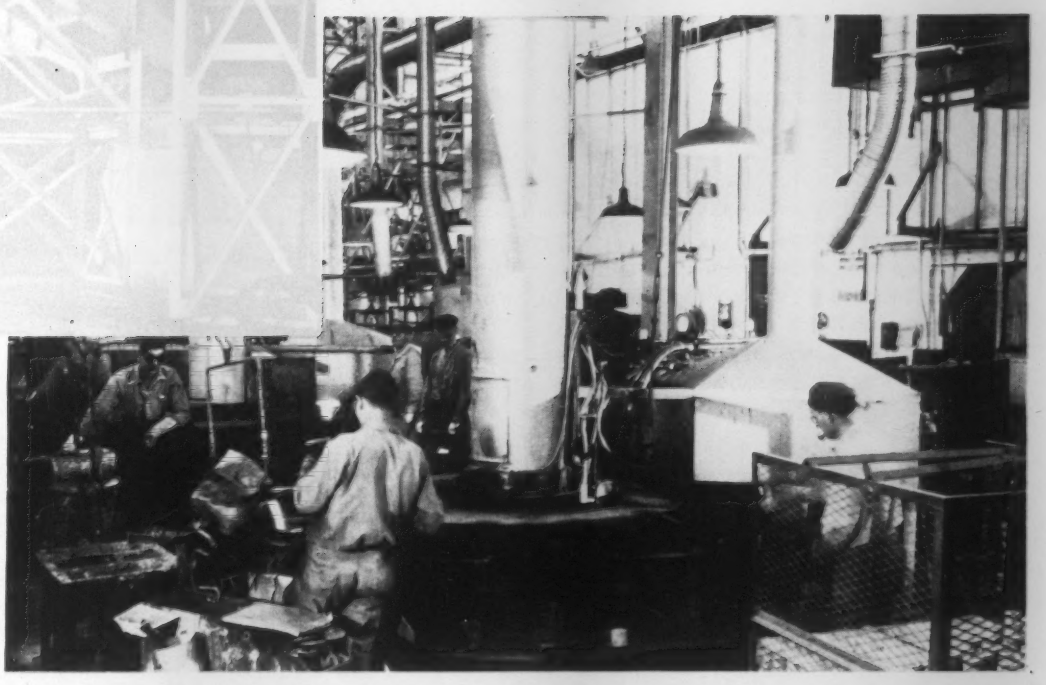
Analyzing the Problem

Since the problem of automation finally resolves itself into strictly an economic study on ways and means, it might be of interest to follow a product through its incubation period.

A complex electrical unit is before a group of engineers for its tooling layout. Samples have been built and processed to perform such functions as are required by the prospective customer. Drawings and test specifications are available, and the immediate problem resolves itself as to how one is to assemble some 3,500,000 separate parts into 25,000 similar units each working day. Several methods are obviously available. Hand tools and work spaces for many operators is one solution. Low tool cost—high price cost—and lack of uniform quality is certain to come from this approach. Complete automation with the stop and start but-

Fig. 2—Continuous grey iron casting machine

Fig. 1—Automatic cupola charging equipment



ton and an easy chair for the operator is another solution. Very high tool cost, high machine maintenance, low piece cost, and good quality of product will likely be the result of such an approach. The bare economics of the study will dictate some inbetween procedure as the solution. Each subassembly will be weighed on its merits, and its method of manufacture as well as the assembly and testing will be governed by experience and ingenuity of the tooling staff. In the analysis the comparison of tool and piece price can be readily understood, but it is considered that the statement as to quality should be clarified.

Automation has repeatedly demonstrated that if the operation is to be effective, the automatic unit must be supplied with parts of uniform quality. A stamped part slightly off form, a subassembly improperly assembled or an improperly wound coil simply will not fit into the work station provided in a machine, whereas an operator can, with hand tools, sometimes build up such subquality assemblies. In the fields of testing much automatic equipment has been introduced, for it is a well-established fact that the human eye, and the human hand will, after hours of repetitive effort, see or hear or feel things which are not there.

Automation at Work

In the highly complex processes and the diversified field of endeavor existing here, there are many examples of automation. No process can be said to have been reduced to complete elimination of operating personnel, nor can it be construed to be the ultimate solution. We have problems—lots of them, and improvement possible in almost any application. Perhaps it would be of interest to review a few such examples of automation which are in daily use here.

Castings: This Division operates a rather unique captive gray iron foundry utilizing casting of metal into permanent molds. Cupola charging equipment, *Fig.* 1, automatically weighs and loads charges of material into the charging area. Grey iron parts are cast continuously on a rotary casting machine, *Fig.* 2. These machines have been in operation for many years, and are comprised of

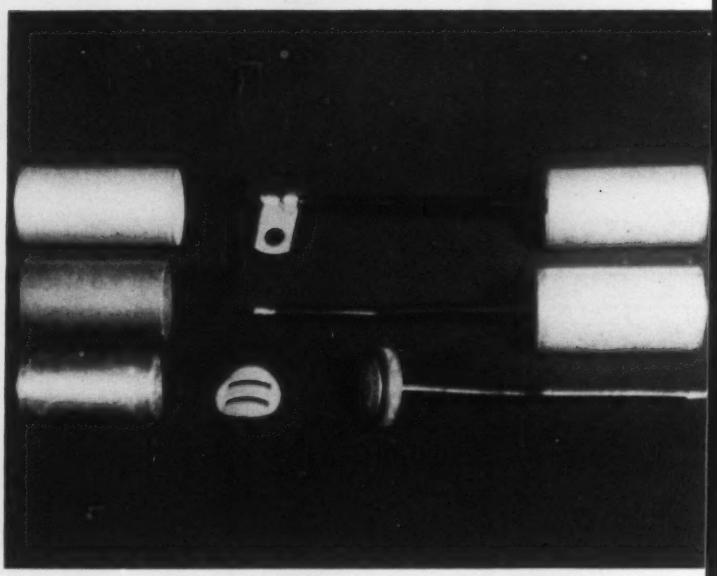


Fig. 3—Component parts of automotive condenser

continuously revolving tables on the periphery of which are located grey iron molds parted at the center line of the casting and actuated by air cylinders. Mold surfaces are coated with soot from a low pressure acetylene flame after each pouring. Sand cores are set in special holding fixtures. Hot castings are dropped from the machine into conveyors, carried through the annealing process, and to the cleaning department. Considerable elimination of fatiguing work and hazardous working conditions has been accomplished.

Automotive Condensers: Condensers such as shown in *Fig.* 3 are produced on the automatic in-line machine of *Fig.* 4. Operations of such a machine are complex and difficult to explain. In *Fig.* 4 the assembly stations are moving by index from right to left. The right hopper feeds the can into the nest, turning each can right side up as it drops through the tube. The center hopper feeds the insulating tube, and the left hopper feeds the wound foil condenser. Intermediate stations insert the spring tension washer and check after each operation to see that the parts are in place. *Fig.* 5 is a closeup of the assembly machine at its extreme left. Parts are transferred from the index stations to a timed dial into whose nests are placed the lead assembly. After the case is crimped the unit is transferred to an automatic clip, weld, and test machine where the assembly is completed.

Condenser winding machines, *Fig.* 6, feed two strips of foil and four strips of insulating paper onto an arbor upon which is wound the standard automotive condenser. Cycle of each machine is completely automatic, with ends of foil taped and tension accurately controlled. A closeup view

Fig. 6—Condenser winding machines

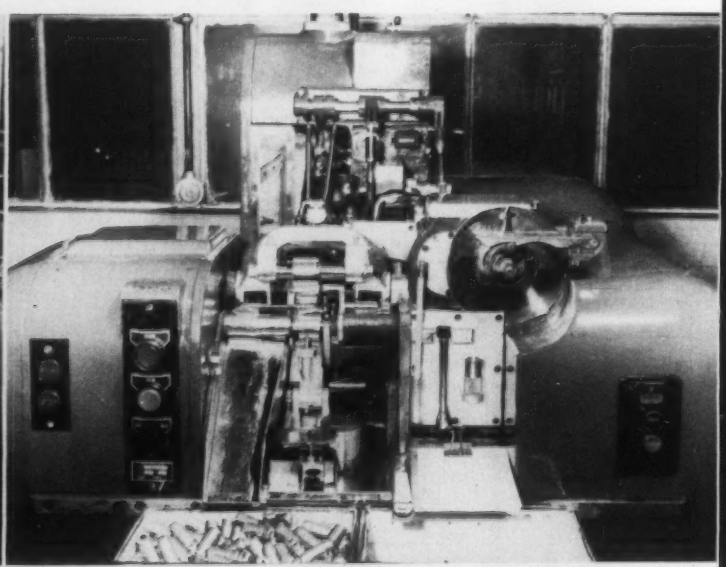


Fig. 7—Closeup of condenser winding

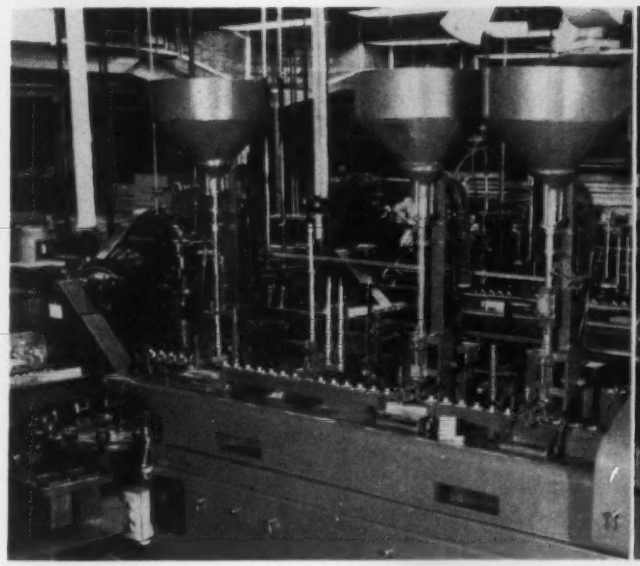


Fig. 4—Assembly machine for condensers

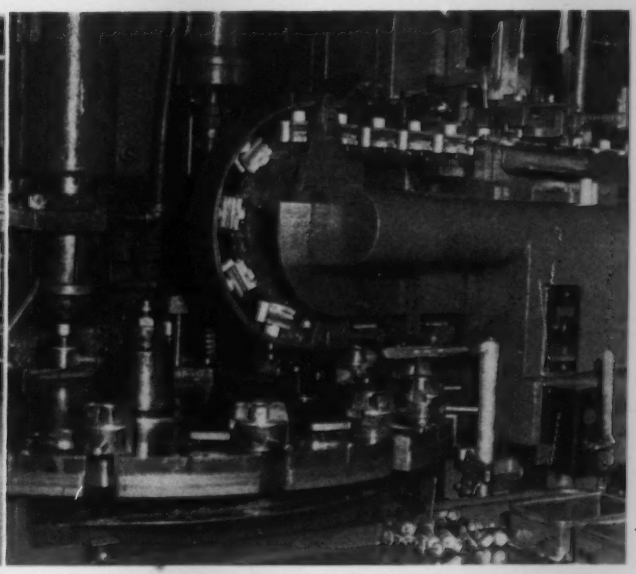


Fig. 5—Closeup of condenser lead assembly

is shown in *Fig.* 7.

After the condenser coils are wound the parts are hopper fed into an automatic inspecting machine, *Fig.* 8, which checks each unit for capacity and for size. Machine error can quickly be detected by the automatic separation of the rejected parts.

On special machines, *Fig.* 9, secondary coils are wound with many thousands of turns of #40 wire, each layer of 420 turns insulated from the next layer with special paper. The cycle is completely automatic except for the sanding and connecting of the starting ends. Ten coils are wound at a time, and the cycle of the machine is stopped if a wire is broken.

Generator Armatures: A photograph of the component parts of the generator armature, *Fig.* 10, is shown to facilitate understanding of the machines shown in *Fig.* 11. It will be noted that the turns of wire, cotton covered, are so positioned that the ends of the coils cross to relieve pressure in assembly. These machines wind these coils,

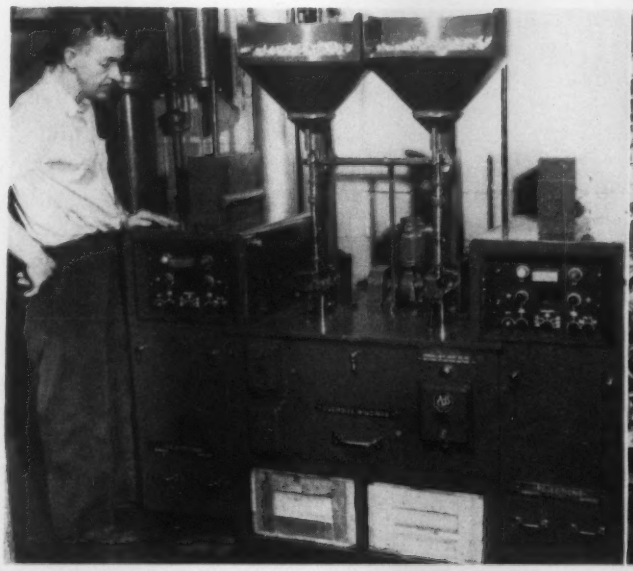


Fig. 8—Condenser sorting machine

Fig. 9—Secondary coil winding machine

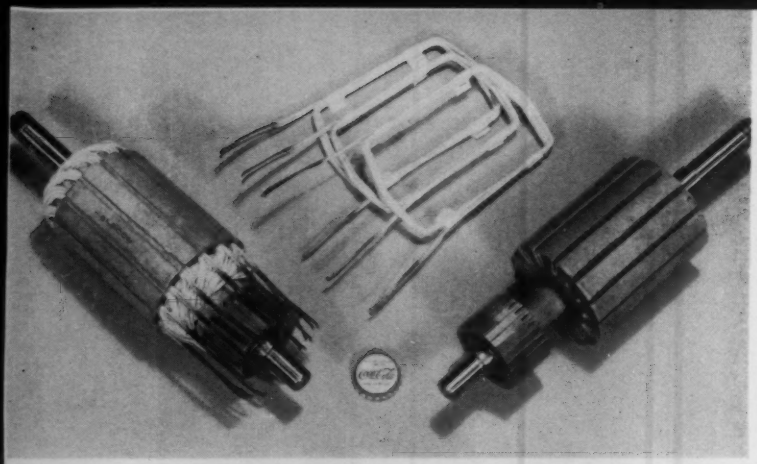


Fig. 10—Generator armature assembly

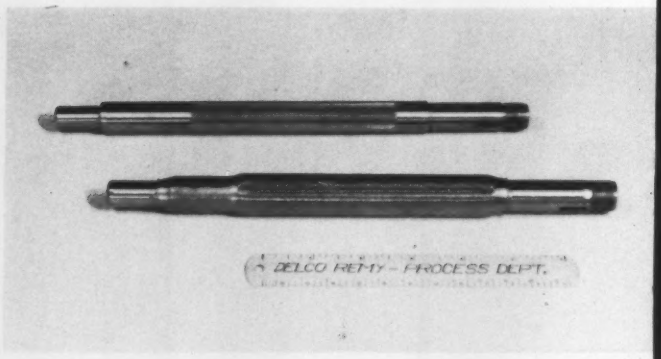


Fig. 13—Generator armature shafts

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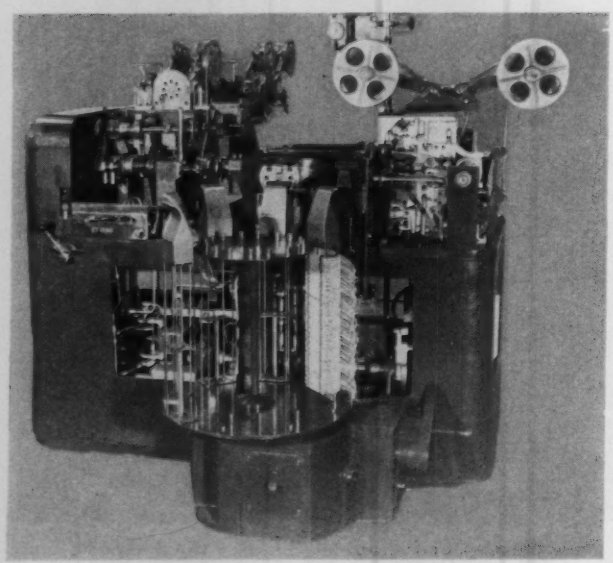
Fig. 11—Generator coil winding machines

Fig. 12—Closeup view of coil winding



place the heat sealing tape at the four corners, and drop them on racks ready for insulation removal. Again the cycle is fully automatic, and wire breakage or misalignment will stop the cycle. *Fig.* 12 is a closeup view of a machine with all guards removed.

In *Fig.* 13 is shown representative generator shafts produced. The upper shaft is a sample of millions which have been made by automatic screw machine operations. The lower shaft has been made by equipment shown in *Fig.* 14. Flat stock in coil is fed into a tube mill, formed, welded, and cut off in continuous operation. Both ends are formed with radii and fed into extrusion presses shown in this photo. From there they are taken to machines to have the key seat blanked, the body diameter ground, and the driving key sheared on the lamination diameter. All operations are timed to a synchronized line flow, and the parts are fully conveyed between operations.

Process requirements called for bakelite parts into which metal inserts must be molded. To reduce cycle time and decrease hazards of loading these inserts special machines were developed, *Fig.* 15. Material is heated electronically and fed through the funnel-shape orifice into molds located on a rotating dial. The curing process on each shot can be accomplished while inserts are loaded outside the area of compression.

The cranking motor armature is so designed as to provide rectangular sectioned wire assembled into insulated slots in the lamination. *Fig.* 16 shows the method of hand assembly used for many years and *Fig.* 17 shows one of several automatic machines now used to insert these wind-

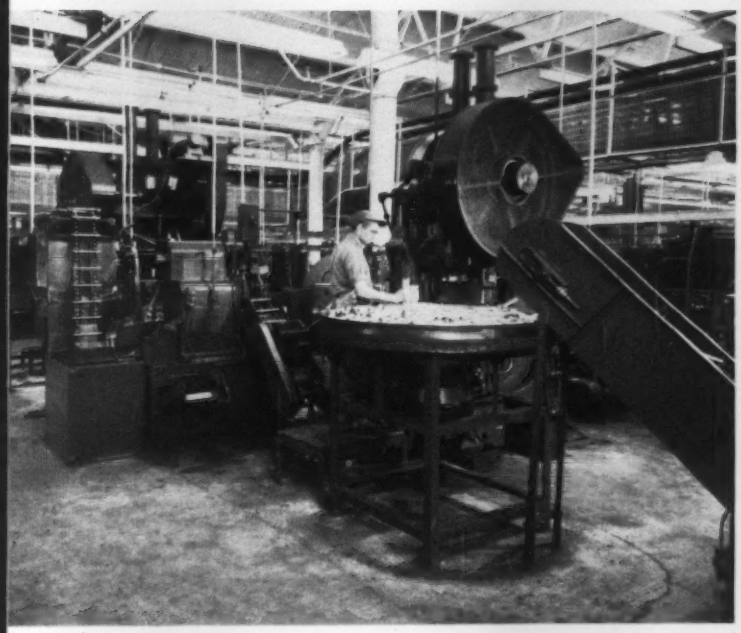


Fig. 14—Machines for armature shaft extrusion

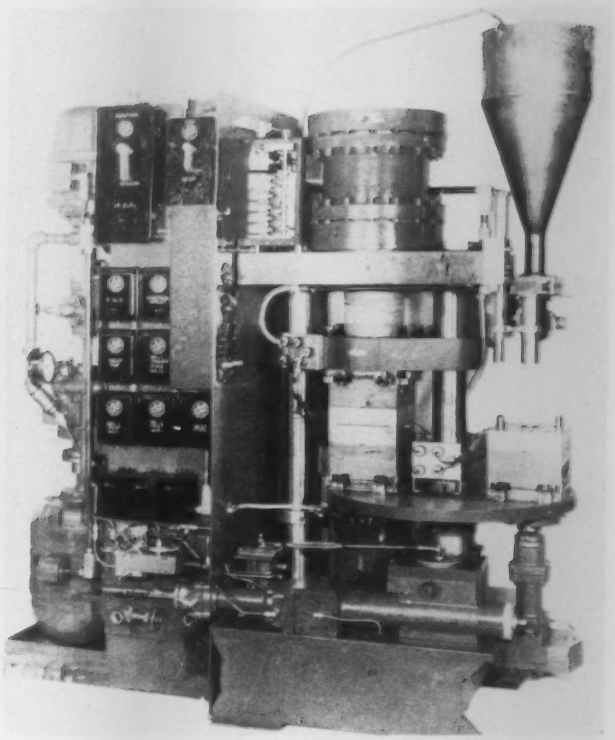


Fig. 15—Bakelite molding press

ings. The hairpin shaped section is blanked and formed on a press not shown and brought automatically by conveyors from the left into assembly position. There the coils are dropped into gathering nests, assembled and spaced with fingers, and inserted by a ram into the lamination and core assembly shown between the two gathering heads.

In-Line Assembly Machines: In the field of automatic assembly machines there have been many avenues of approach. Commercially available are many types of dial feeds, and many designs of automatic feeding devices. This equipment is excellent, for the most part, and its use so commonplace as to be of little interest for this discussion. We use such equipment in hundreds of applications. Some years ago, however, it was felt that a definite need existed for equipment which fulfilled certain requirements beyond those available on the market. Dial operations are restricted by the mechanical limitation of size and construction of the

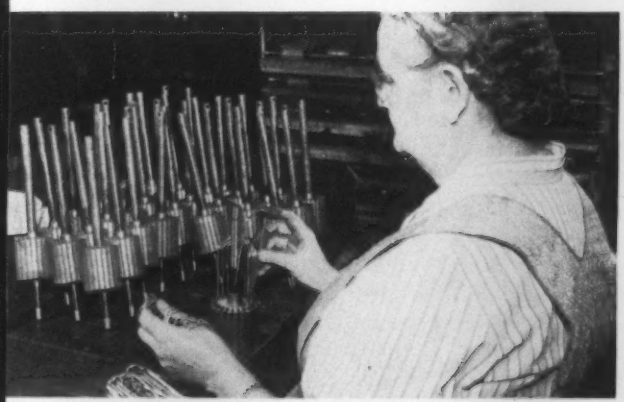


Fig. 16—Hand method of armature assembly

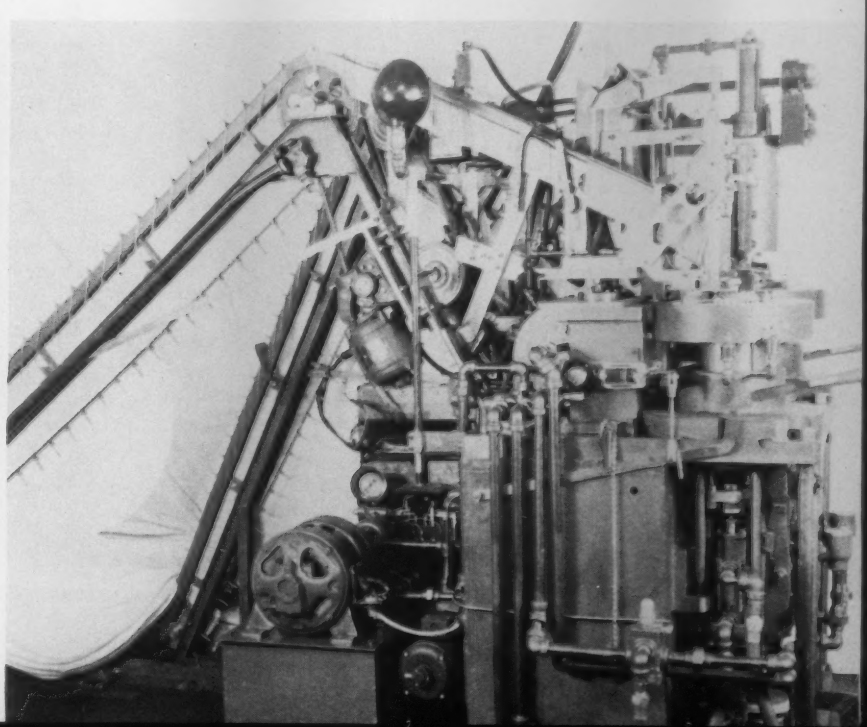


Fig. 17—Automatic armature assembly

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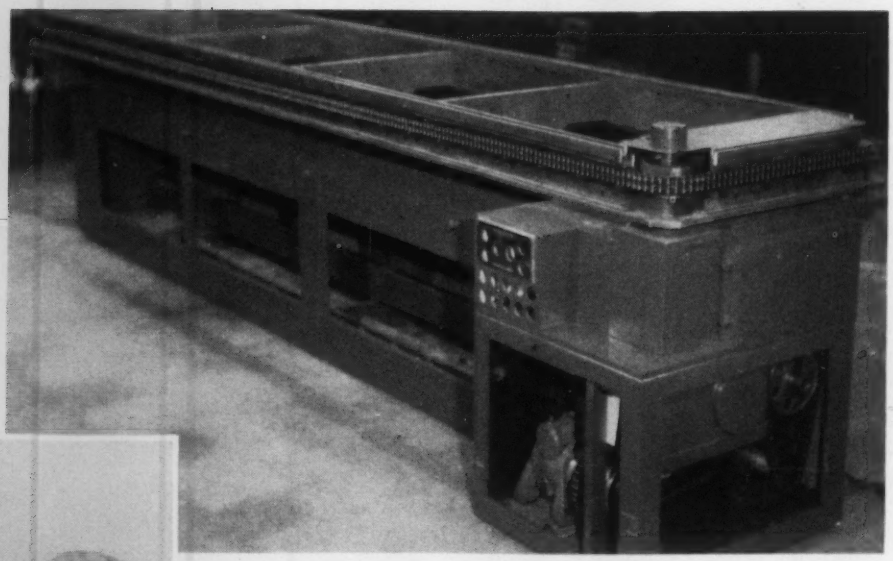

Fig. 18—Typical in-line assembly machine base

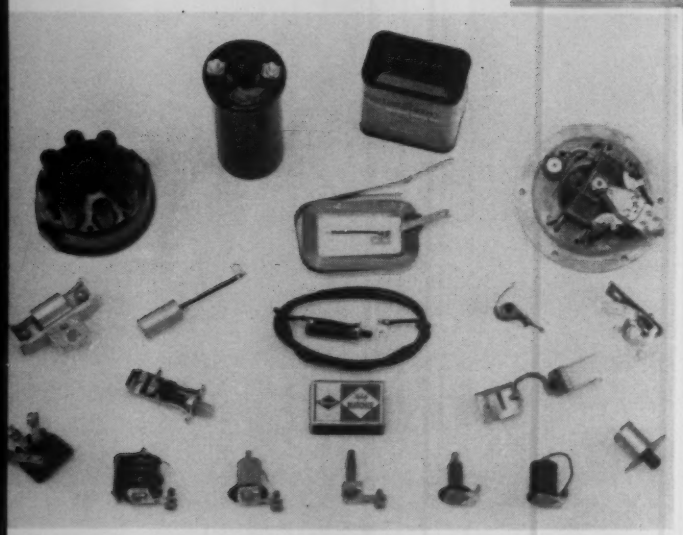

Fig. 19—Sample assemblies run on in line units

Fig. 20—Machining of distributor caps

dial, and the number of operations which might be used—so in 1945 the first of a series of so called "in-line" machines was developed. Several basic premises were made in its design.

1. A standard base would be developed to accommodate any type of operation to be preformed within the scope of such equipment.

2. Stations would be indexed by a drive which could be readily changed as to index cycle and dwell time. Stations were to be moved on the periphery of the base by chain, and would be supported where necessary at work stations. On very accurate operations either the part or the machine tool would be floated. A cam shaft was to be installed the length of the base upon which could be clamped split cams of such design as to activate necessary electrical, hydraulic or mechanical motions as would be required by the machine.

3. No installation was to be made which would be hazardous to the operators safety.

Such a base is shown in *Fig.* 18, and these basic principles have been carried through the more than sixty machines that have been built to date. Limited variation of length and width of track have been made for specific application. The following illustrations are a few of the applications of such machines. It will be noted that drilling heads, punch presses, welders, milling heads, printing presses, automatic scales, feeding devices, and complex testing equipment are all combind to perform coordinated operations. *Fig.* 19 shows a few repre-

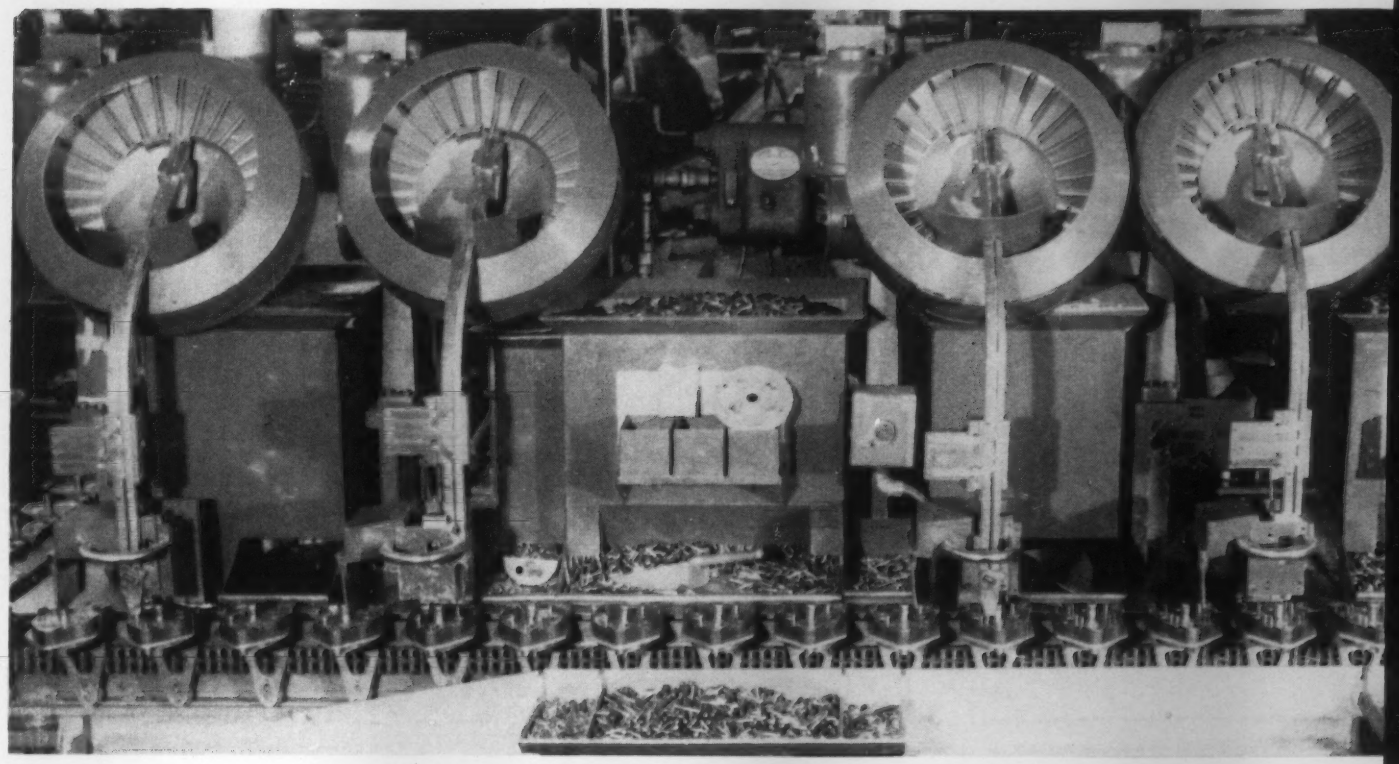

Fig. 21—End bearing assembly machine

sentative parts upon which operations have been performed by these versatile machines.

On the machine in *Fig.* 20 is placed the bakelite casting as it comes from the presses with the terminal inserts molded in. Note the special drilling heads which machines the cap registers, and machines the inserts. A carbon button is inserted and staked, and the vent drilled for cap ventilation. In addition, this machine also performs a very high voltage dielectrical test to insure a quality product. Note the use of conveyors to and from the machine to reduce handling time and part damage.

In the immediate center of the end bearing assembly machine of *Fig.* 21 is a cranking motor end frame. This machine assembles the four ground and the four insulated brush pins, the locating dowel pin, and where used, a steel plug over the shaft bearing. Note the use of commercially available hopper feeds.

View of the circuit breaker assembly machine

Fig. 22—Breaker lever machine

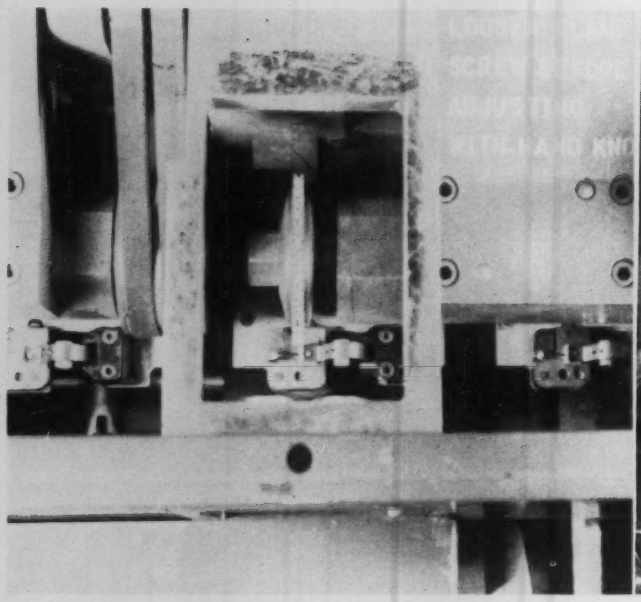

Fig. 23—Milling operation on breaker lever

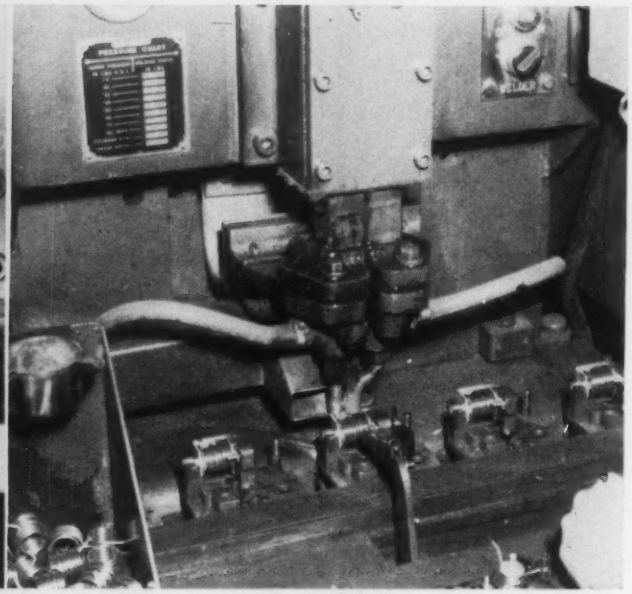

Fig. 24—Welding and cutoff of relay coils

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is shown in *Fig.* 22 and of the milling operation on the breaker lever in *Fig.* 23. This photo is a closeup of the station upon which contour of breaker rubbing block is milled on the special assembly machine.

Welding and cutoff operations on relay coils are shown in *Fig.* 24. This photo is a closeup of the welding operation on the voltage regulator coil and illustrates application of resistance welding.

Service shipping schedules permit the application of automation even in the processes of packaging. *Fig.* 25 shows a few of the machines de-

Fig. 26—Printing operation in packaging

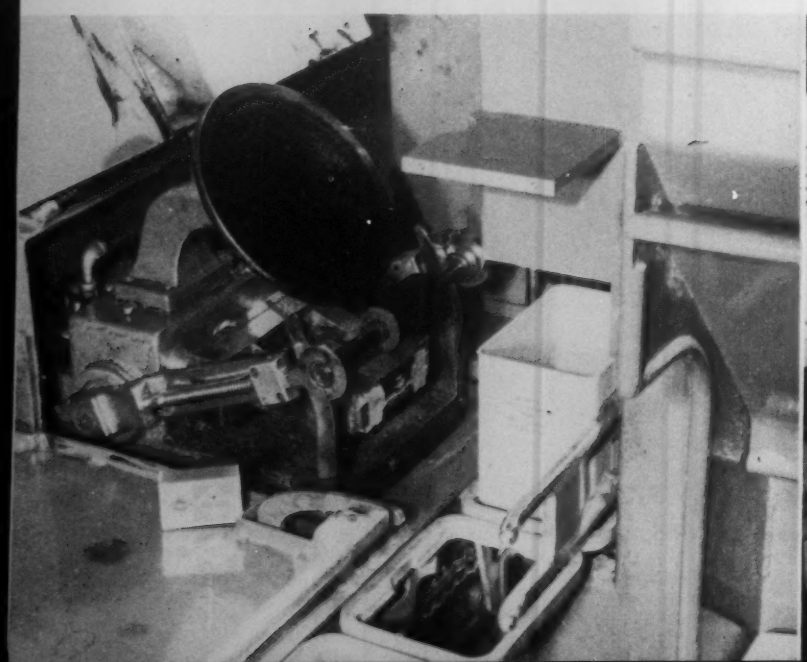
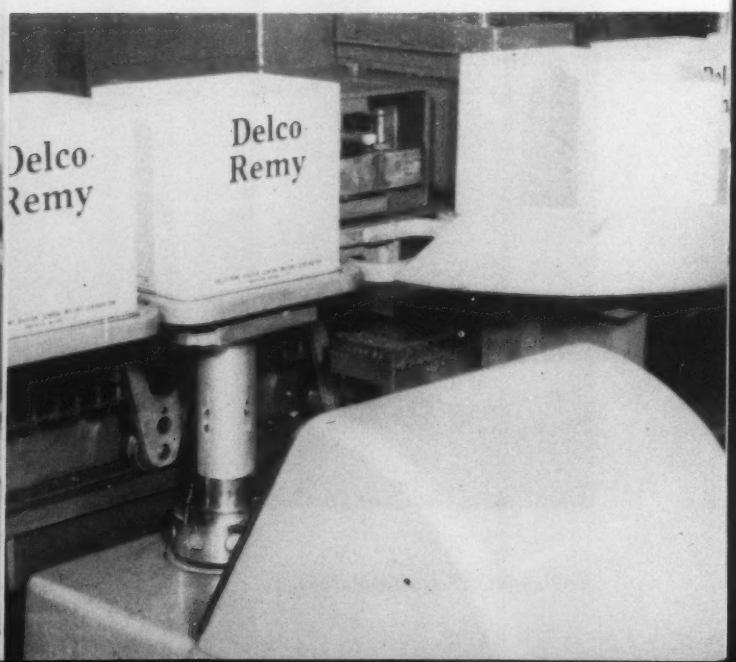


Fig. 27—Weight checking of packages



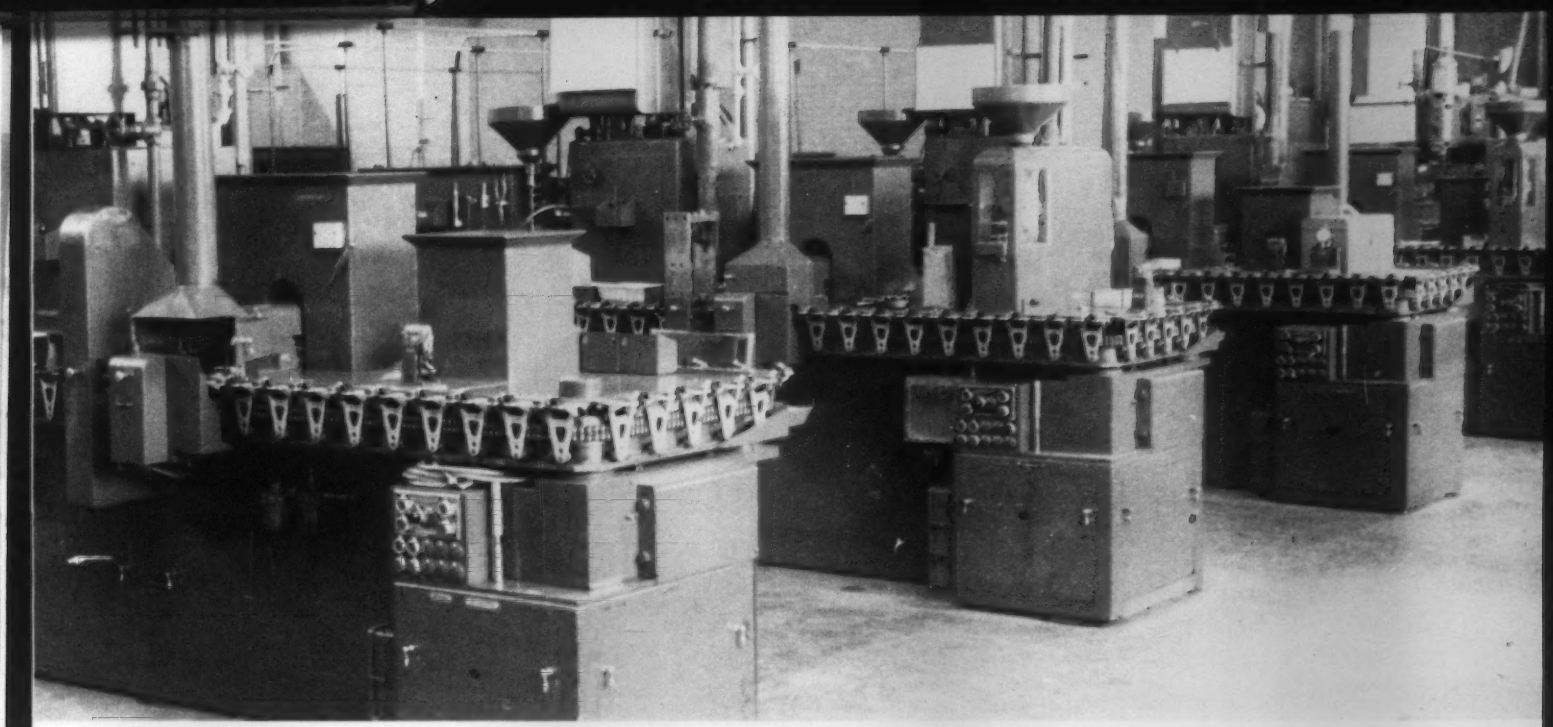


Fig. 25—Automatic packaging machines

veloped for these applications. Empty cartons are loaded in nests on the indexing stations and passed successively through a printing press, *Fig.* 26 where the number, quantity and description are imprinted; through a sizing operation where the cans are shaped; through a battery of heat lamps to dry the printers ink; through the loading area where the parts are fed into the machine; through the scales where the quantity is checked, *Fig.* 27; through a seamer which inserts and seals the cap; and back to the operator who loads the machine, where the boxes are unloaded and placed in cartons.

Economics of Automation

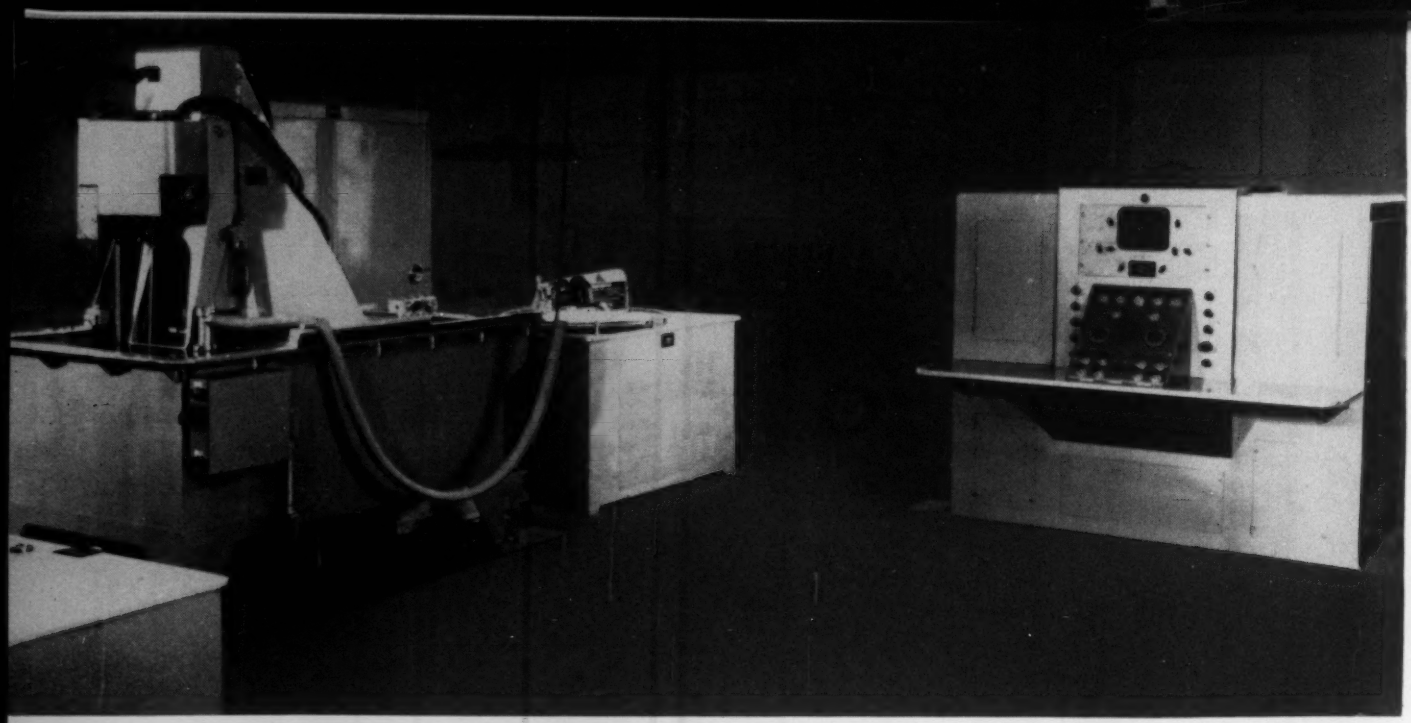
We who work with this fascinating field are convinced that the field of automation is in its infancy. Although progress has been considerable here at Delco-Remy, rarely comes a problem to which automation cannot be applied to some extent. It is an endeavor which cannot be approached with temerity, and requires an understanding and far-sighted management. The economic aspects of each problem must be reviewed on its own merits.

From the beginning of a study of a machine for a particular assembly, production supervision is in regular contact with the development. At the final tryout stage, production operators are brought to the department and production supervision aids in the training. In addition, conferences with product engineers are held to consider changes of the parts to be assembled. These changes are judged by their value in improving both production rates and the quality of the product.

As a machine is "bugged out"—a vital and necessary operation with automatic equipment—the production rate increases until the machine is operating at its normal rate. During this time it is studied by the standards department to set production rates. When the rate is agreed upon, the machines are moved to the production department.

Although not essential, it is desirable that a mechanic from the plant receiving the machine spend some time in the "in-line" department to become familiar with the equipment. If the mechanics from the "in-line" department were required to service the machines out in the production departments, their time available to produce additional new equipment would decrease as more and more machines were placed in use. The facilities to service these units properly are as necessary as those to produce them. The productive use of such equipment reduces labor cost but inevitably requires more skilled mechanics to service it.

The day of the "pushbutton" factory is not on the immediate horizon. When it does become a reality, it will be the result of coupling together individually mechanized units of the in-line type. Although Delco-Remy's products still involve a fair percentage of hand assembly operations, additional experience and the co-operation of product engineering will continue to reduce hand labor. The experience with the 50 machines now in operation conclusively proves that in-line machines can make a substantial contribution towards our technological goal of reduced production costs and improved quality.



1 SIMAC (sonic instrument measurement and control) installation for determining internal defects in jet engine rotor forgings consists of; a set-up table, on which the part is positioned for inspection; an immersion tank in which the part is rotated under the scanning machine; a control cabinet to house the components which co-ordinate the actions of the system; a recorder with turntable to plot the inspection results; and an electronic console unit with the ultrasonic Reflectoscope screen and control panel buttons and knobs employed by the operator.

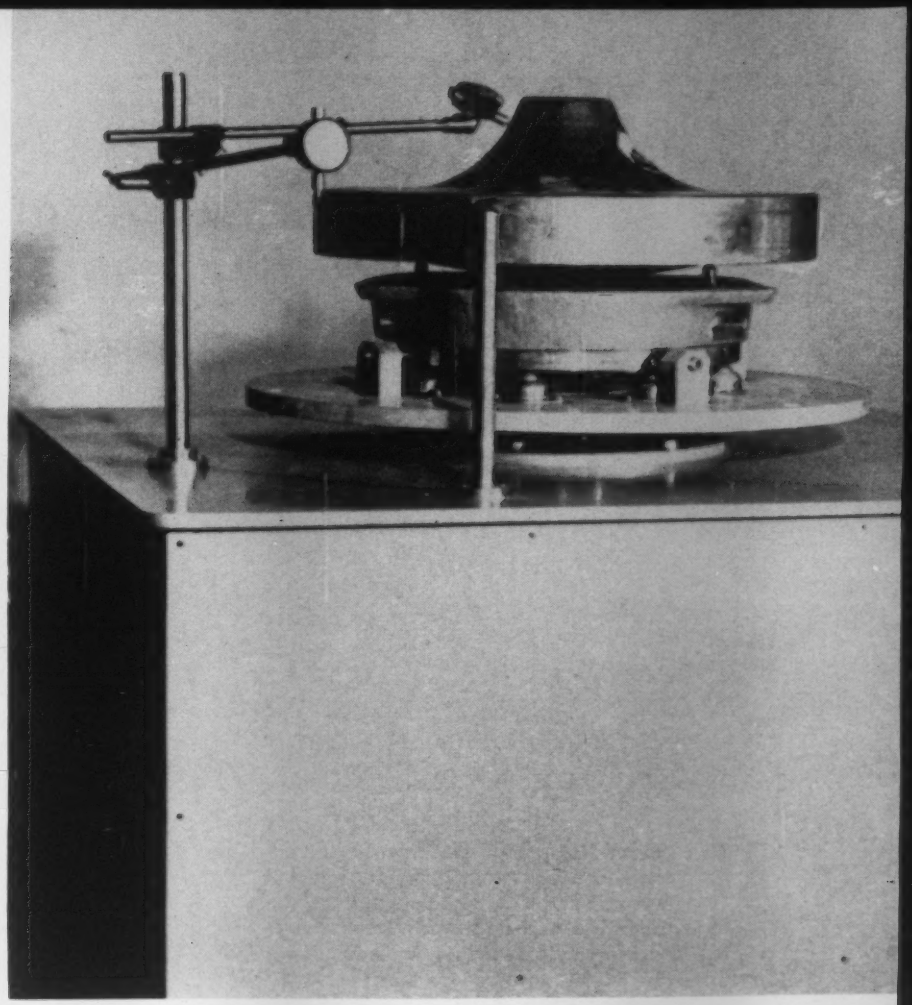
AUTOMATION TODAY

SYSTEM INSPECTS AND RECORDS

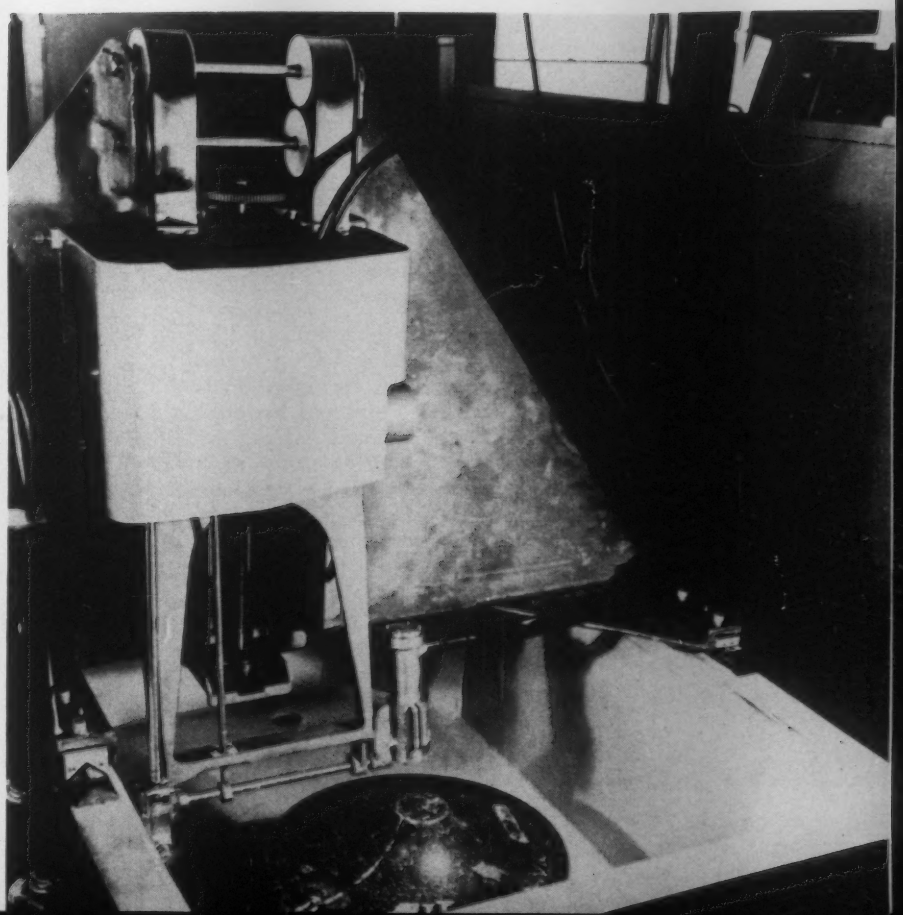
FEATURING PUNCHED TAPE programming of automatic scanning means and simultaneous recording of inspection results, the SIMAC (sonic instrument measurement and control) installation at Allison Div., General Motors Corp. accomplishes a task which would be tedious and impractical to perform manually. Nondestructive testing of materials to discover internal defects and ascertain their relative importance before long and expensive machining operations are begun is a cost saving practice which assures higher quality of finished parts. To accomplish this purpose on jet engine rotor forgings and other parts which are circular in plan, Sperry Products Inc. developed this equipment utilizing an ultrasonic Reflectoscope as the basic detection device.

The principle employed in this ultrasonic testing involves the emanation of short bursts of sound at 5 million vibrations per second from a quartz crystal transducer. Because these vibrations cannot be heard by humans they are termed "ultrasonic". When such a search unit is brought into intimate contact with the testpiece, unwanted discontinuities within the material reflect these beams as echo signals. In this application water serves as an efficient conductor of the sound waves and eliminates the need of machining the rotors smooth before checking. The echo signals are plotted on the round graph paper as a record of defects and shown on the cathode ray tube where they may be viewed by the operator.

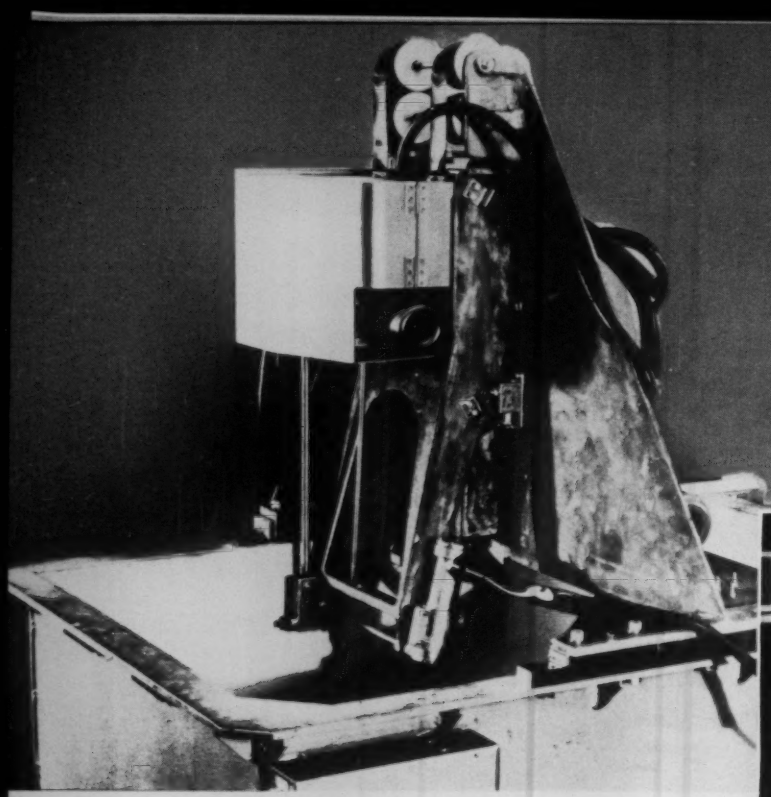
Complete scanning of the entire workpiece is automatically accomplished in 15 minutes by the machine which is operated by the punched program-controlling tape specially prepared for each design of part to be checked. A production line inspection device, the system was designed for the repetitive inspection of duplicate pieces.



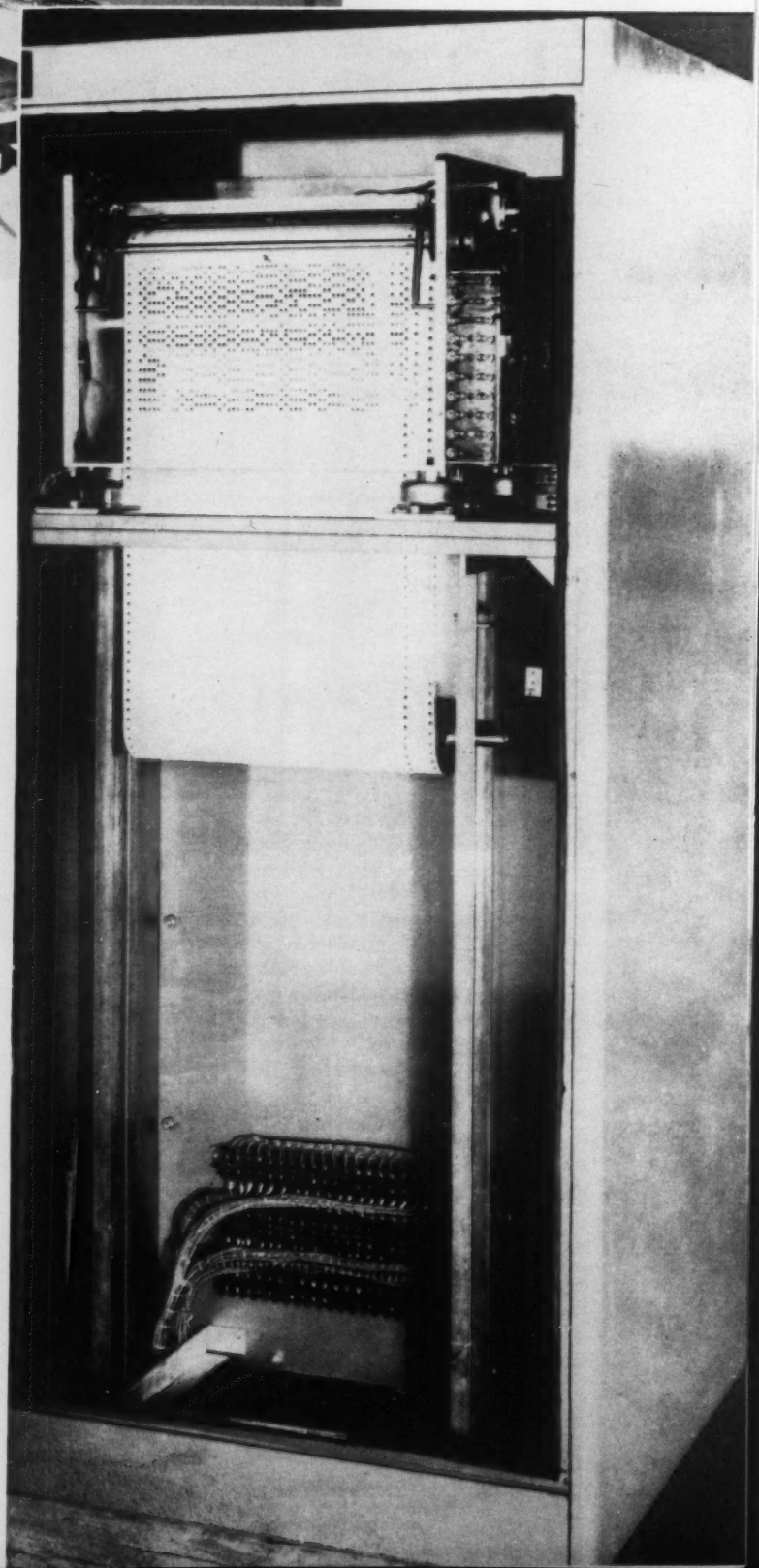
2 Setup table has a portable turntable with set screws and indicators which are used to align the parts. Each piece must be prepositioned in this manner so that it will maintain a proper relationship with the programming system while undergoing the ultrasonic examination. After the correct alignment has been established the specimen and setup turntable are transferred to the inspection tank.



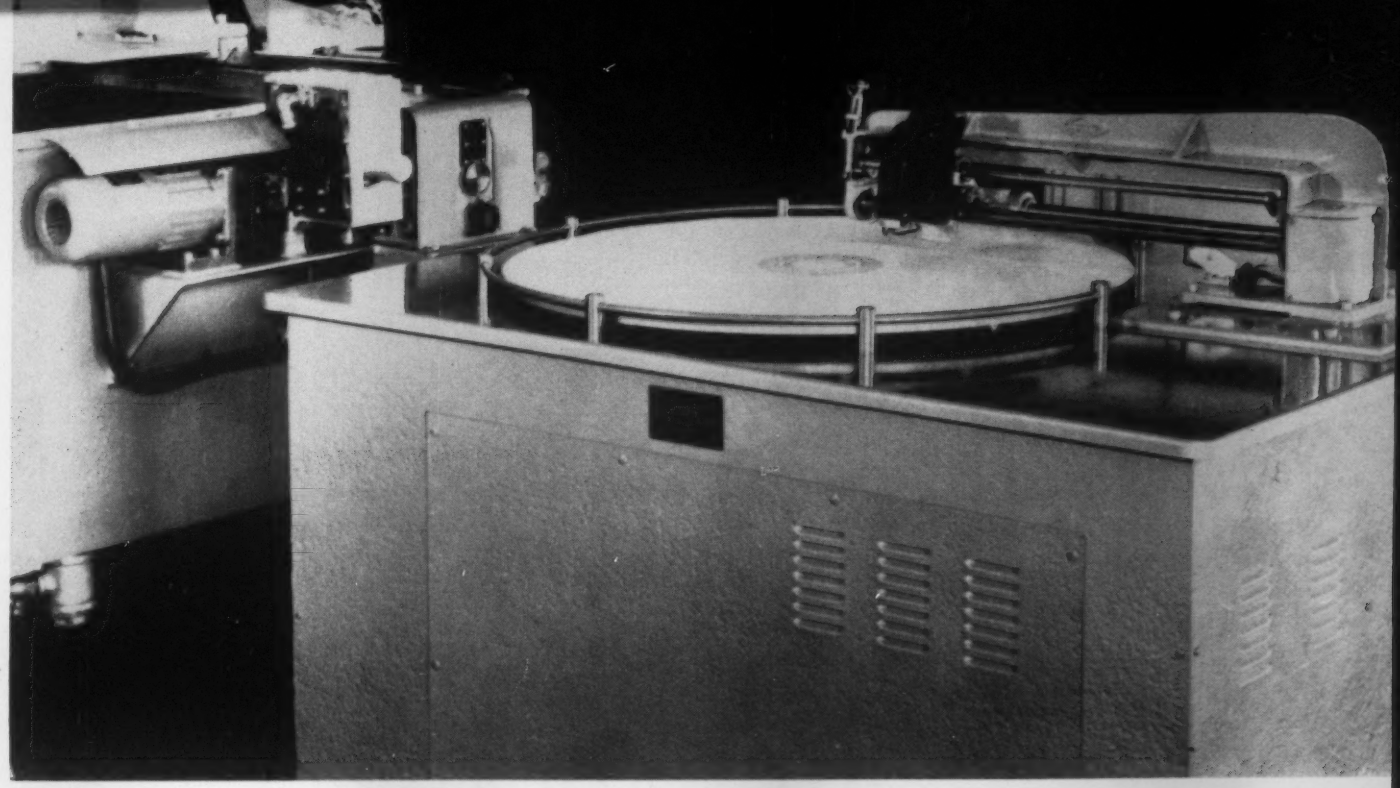
3 Workpiece is held in position on turntable by needle stays and placed in the tank with enough water to completely immerse testpiece and search unit. Water serves as a conductor for the sound waves probing the part. These ultrasonic beams must enter the specimen perpendicular to the surface; therefore the scanning head must pivot to the proper angle as it moves the search unit out radially to successively larger scanning circles. The drive for operating the scanning turntable and the recording turntable mechanisms has a wide speed range, electronically controlled motor. A programmed sequence of motor speeds adjusts the rotational speed of the turntable to maintain nearly constant scanning speed.



4 Above—Scanning machine is a rectangular tank with turntable in the bottom and horizontal ways at the top. The carriage slides on the ways and is positioned by a lead screw and nut. Affixed to this horizontal moving unit is a smaller second carriage on vertical ways. This carriage holds the pivoted scanning head whose search unit is continually moved, horizontally, vertically, and angularly by servomotors actuated by signals from the punched holes in the program tape.

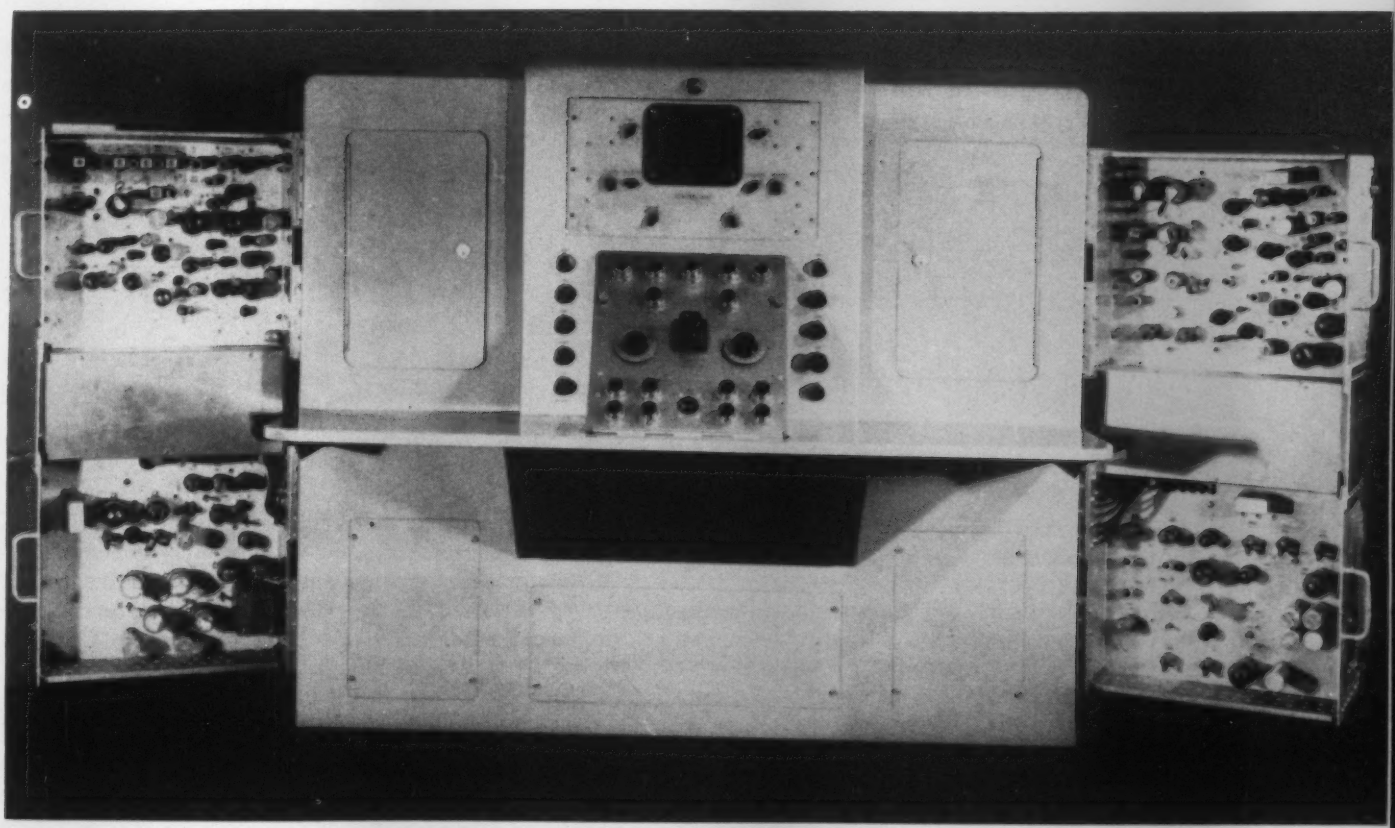


5 Right—Program of operation of the entire system is set up on an accessory unit (not shown) that provides a tape with 60 holes punched for each scan line. The tape feeds through the control cabinet where holes for each function of the scanning machine (three motions of the head, speed of the turntable, ultrasonic power level and four other control functions) can provide up to two hours continuous and automatic control of scan line sequence. This control cabinet contains electronic components for operating the various positioning devices and presenting the tape information to the console for visual observation and manual control.



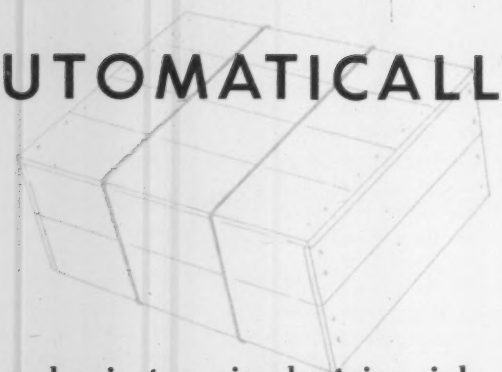
6 Above—Chart of 28-inch diameter is rotated on the recorder by the same power unit that rotates the scanner turntable so that a synchronous relationship is maintained. A recording pen advances radially on the chart for each test position occupied by the search unit. Beams reflected by structural discontinuities are logged as a permanent record of all ultrasonic echo signals reflected from the search unit. This aids interpretation of the test in process and can be filed for reference.

7 Below—Electronic console is the operator's station from which point he may control the machine manually or start automatic testing. All ultrasonic echo signals are visually displayed on the face of the cathode ray tube to provide the operator with visual monitoring of data recorded on the chart. The entire electronic chassis is mounted on hinges and shown swung out in position for maintenance.

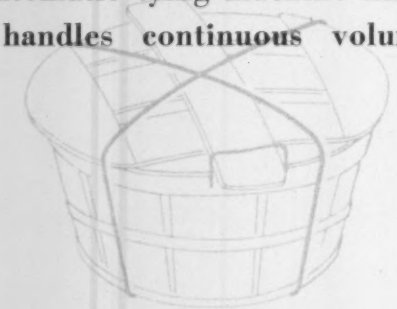


TIE IT WITH WIRE

AUTOMATICALLY



Packaging can be just a simple tying job—in fact the simplest bundle to form by hand is a rope or wire wrapped package. The automatic tying machine improves on hand wrapping and handles continuous volume production



BUNDLE TYING is certainly one of the simpler forms of packaging, yet the wire-tying operation does not readily suggest an automatic process. Although shoelace-tying machine inventors would probably have many solutions, a machine to bundle automatically must be economic in initial cost, operation and maintenance. It must do a better wrapping job and be faster than hand tying.

After examination of specific needs of many industries, requirements of a newspaper mailroom were adopted by the Wiretyer Corp. as the composite specification for development of an automatic bundle tier. Newspapers must be bundled with speed, bundles must be compact to facilitate handling and save truck space, and of course, the operation must be low in cost. Newspapers are soft goods that must be kept wrinkle free and the bundling equipment must be extremely dependable.

Pneumatic operation enables these requirements to be satisfied in the Wiretyer, *Fig.* 1, and also makes possible adjustment for gentlest to firmest tying of packages ranging from loose bundles to wooden boxes and metal objects. By accurate control of tension, light-gage wire may be used. The operating cycle is completed in less than two seconds and as many as 1500 bundles per hour, single or double tied, are possible.

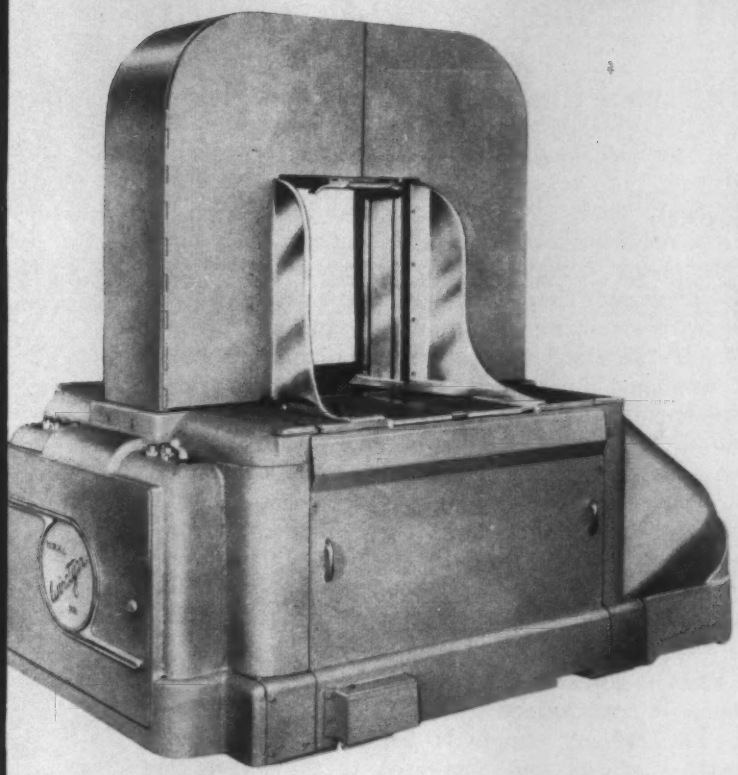


Fig. 1—Automatic package bundler may be fed either by hand or from an automatic-feed conveyor table. Single or double-tied packages, up to 1500 per hour, may be handled by one machine

Operating Cycle

In machine operation, the package to be tied is positioned either by hand or automatic feed conveyor table. Sequence of operations is controlled by switches that prohibit any subsequent operation if a previous step was not adequately completed. Functions performed in order are straightening, compression, wire wrapping, wire tying, and removal.

The bundle is prepared for wrapping and tying in the straightening and compression operations. A straightener head is moved horizontally across the machine opening to rack the bundle into a neat stack and to hold it in position during the tying cycle. An overhead pneumatic ram is positioned above the package to compress or close the bundle.

Wire laying rings, *Fig.* 2, rotate to wrap wire around the positioned and firmly held package. Each ring, one for each tie, moves through an angular rotation of approximately $1\frac{1}{4}$-revolutions. Double, wire laying sheaves on the rings start from a position in a horizontal plane with the wire gripper heads, just under the bundle, and stop in this same plane but on the opposite side of the gripper heads. Free end of the wire is held alternately in one of two gripper heads and the wire laying ring rotates in opposite directions on each succeeding cycle.

During the initial part of the wire laying rotation, wire is given to a slack takeup device, then fed back to the ring from the takeup device and finally drawn through a wire tensioning brake from the supply coil as required to finish encirclement of the pack.

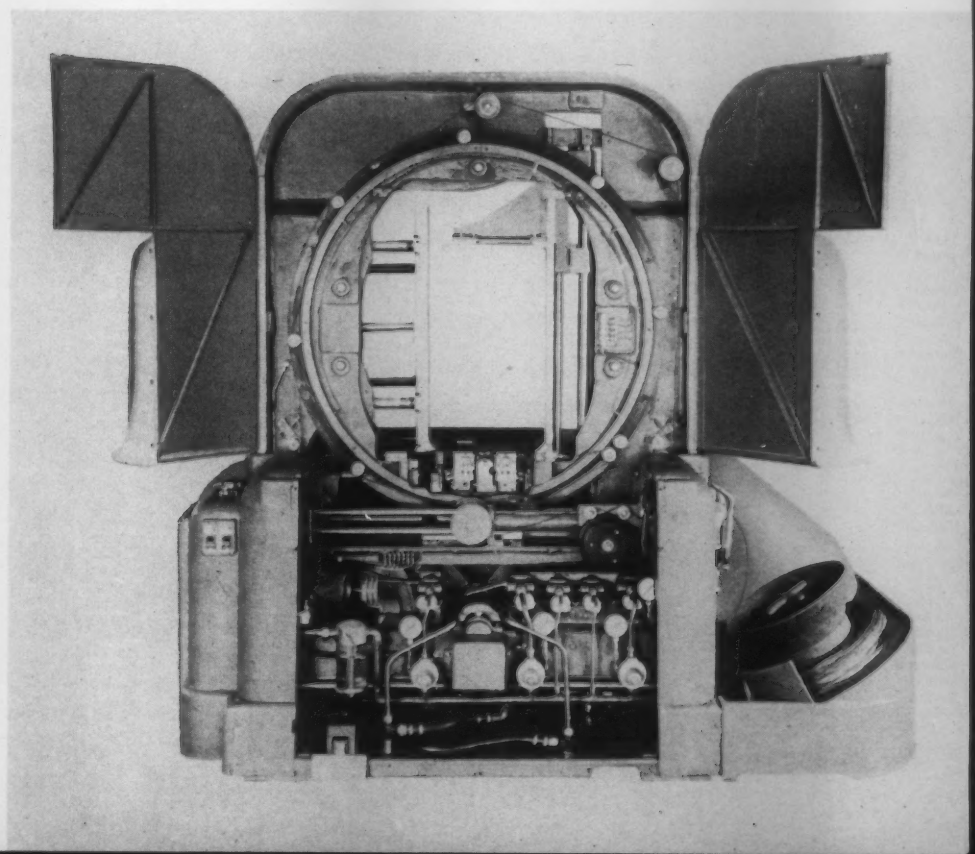


Fig. 2—Bundler with protective coverings opened to show straightener, compressor head, one wire laying ring, double sheave, slack takeup mechanism, and the tying mechanism directly below the package opening

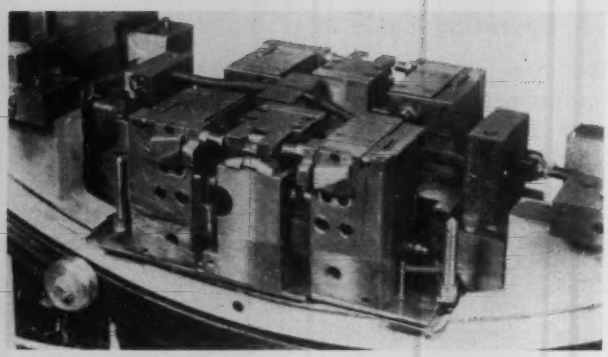


Fig. 3—Tying mechanism for a double-wire tying machine with duplicate devices back to back. On either side of the twister head with twister pinion are gripper heads and wire cutting edges

As the laying ring completes its cycle, wire is drawn into the gripper head opposite the head that grips the free end of the wire. A twister head, located between the two gripper heads, *Fig.* 3, moves forward so that a twister pinion, slotted at the root between two teeth, straddles the double wire passing in front of the tying mechanism. After the gripper heads position the wire in a straight line insuring equal tension and simultaneous cutting of the wire, the twister pinion rotates to twist the wire three times and the gripped ends are cut. Another ¼-turn buries the free ends on the package. After the short piece of wire that was originally the free end is ejected and the tied bundle conveyed from the machine, the unit is ready for another package to be wrapped by reverse rotation. A butt welder is available for joining a new supply of wire, eliminating the need to stop production as a new coil is installed.

Control Elements

Actuation of a limit switch stops the conveyor carrying the package into the machine and simultaneously opens solenoid valves to introduce air to the main drive air cylinder, straightener air cylinder, and compressor air cylinder. After release of a magnetic brake, the main drive cylinder causes the wire strapping operation to begin, and operation of the slack wire control system, consisting of combined mechanical, pneumatic and electrical components, acts to tension wire around the bundle. Each gripper head is powered through its own double-acting pneumatic cylinder, controlled through separate solenoid valves. Twister heads are powered through individual cylinders but controlled by a single solenoid. Twister pinion mechanism is a rack and gear arrangement. Externally supplied air at 100 psi is consumed at a rate of 2.1 to 3.2 cubic feet per cycle.

Electric power from a 220-volt 60-cycle, 3-phase source is transformed to 110, 24 and 12 volts, *Fig.* 4. The 110-volt supply is fed to selenium oxide rectifier stacks and converted to 90-volt dc to power six magnetic brakes. The 24-volt supply is used to control 13 magnetic contactors comprising the sequence control system. The 12-volt supply powers 12 solenoid valves which regulate the air supply to various cylinders. Two ¼-horsepower motors drive the integral feed and eject conveyor tables.

Use of reciprocal mechanical action in wire laying has resulted in saving what ordinarily might be regarded as lost motion. This feature coupled with the wire-tying mechanism and wire tension system, provide fully automatic operation with a minimum of moving parts.

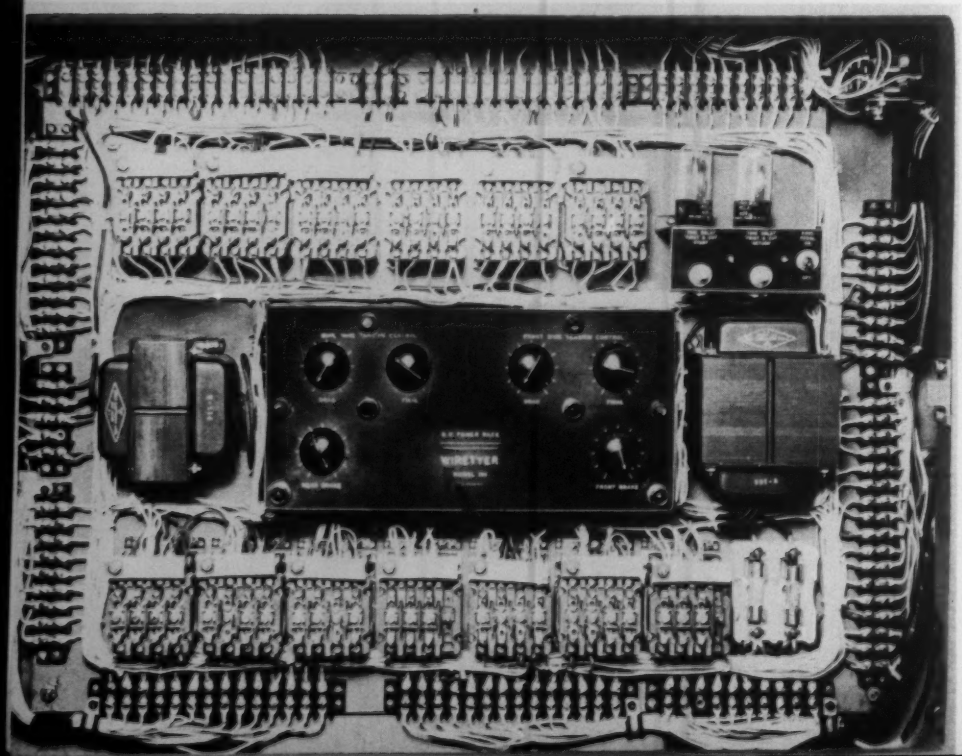
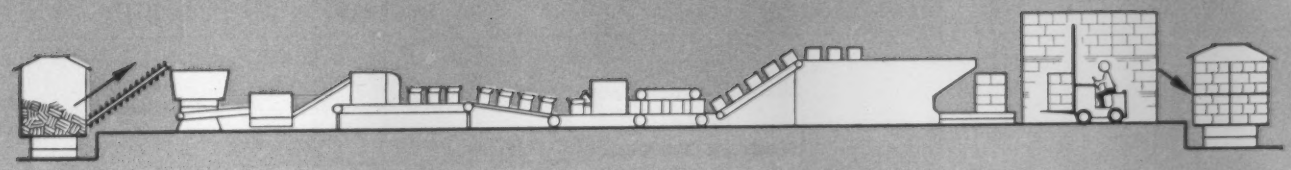
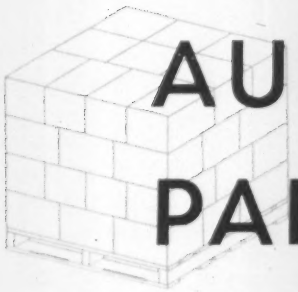


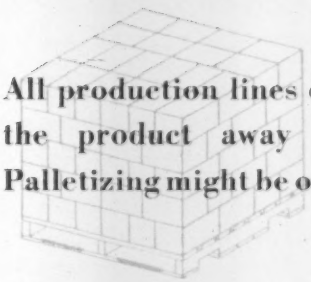
Fig. 4 — Interlocking electrical system with transformers located on either side of control panel. Dials adjust magnetic brakes. Time delay vacuum tubes for the twist and cut cycle are shown above the transformer on the right



ADD EFFICIENCY WITH

AUTOMATIC PALLET LOADING





All production lines end somewhere and the vehicle to move the product away must keep pace with product flow. Palletizing might be one answer, especially if done automatically

MANY PRODUCTION LINES end with the product in cartons which are eventually stacked on pallets. If overlooked or neglected, this pallet loading operation can be a costly and serious bottleneck. Automatic pallet loading effects economies by reduction in work hours required to load pallets, by reducing damage and breakage of cartons, and by improved efficiency of pallet handling due to control of the stacking pattern.

Automatic pallet loaders developed by the Lamson Corp., provide a link between packaging and warehousing. Designed to handle various size cartons from production lines and automatically change pallet pattern, 15,000 cases per eight hour shift can be stacked. Although any number of patterns may be required, in actual practice three or four are considered normal. Spaces between cartons can be provided in one direction for ventilation.

Cases enter the automatic pallet loader on roller conveyors from the packaging line. They are automatically guided into proper alignment, separated to allow room for turning, and then counted by a photoelectric cell which actuates the control mechanism. After cartons are rotated into proper pattern position, rows are formed by a ram moving cartons at a 90-degree angle to the direction of the package conveyor. As rows are positioned on a stripper plate, the layer is formed, stripper plate withdrawn, and the layer drops approximately an inch to the pallet or another layer of cartons. A governor resting on top of the cartons controls the lowering movement and returns the stripper plate for another layer of cases. When a pallet is positioned to receive its first layer from the stripper plate, the next pallet to be loaded has been automatically delivered from the magazine and is ready to be positioned for loading.

Each pallet pattern is governed by an individual pattern cartridge, *Fig.* 1, located at the control panel. A stepping switch forms the desired pattern by counting each carton, and the control relays determine which pattern cartridge is in operation. Each carton pulses the stepping switch, advancing it one position, and when a layer is completed the switch is automatically reset for the next or alternate layer to be formed.

Fig. 1—Individual pattern cartridge which determines a pallet pattern depending on case size. When manual operation is required, patterns can be selected from the control panel

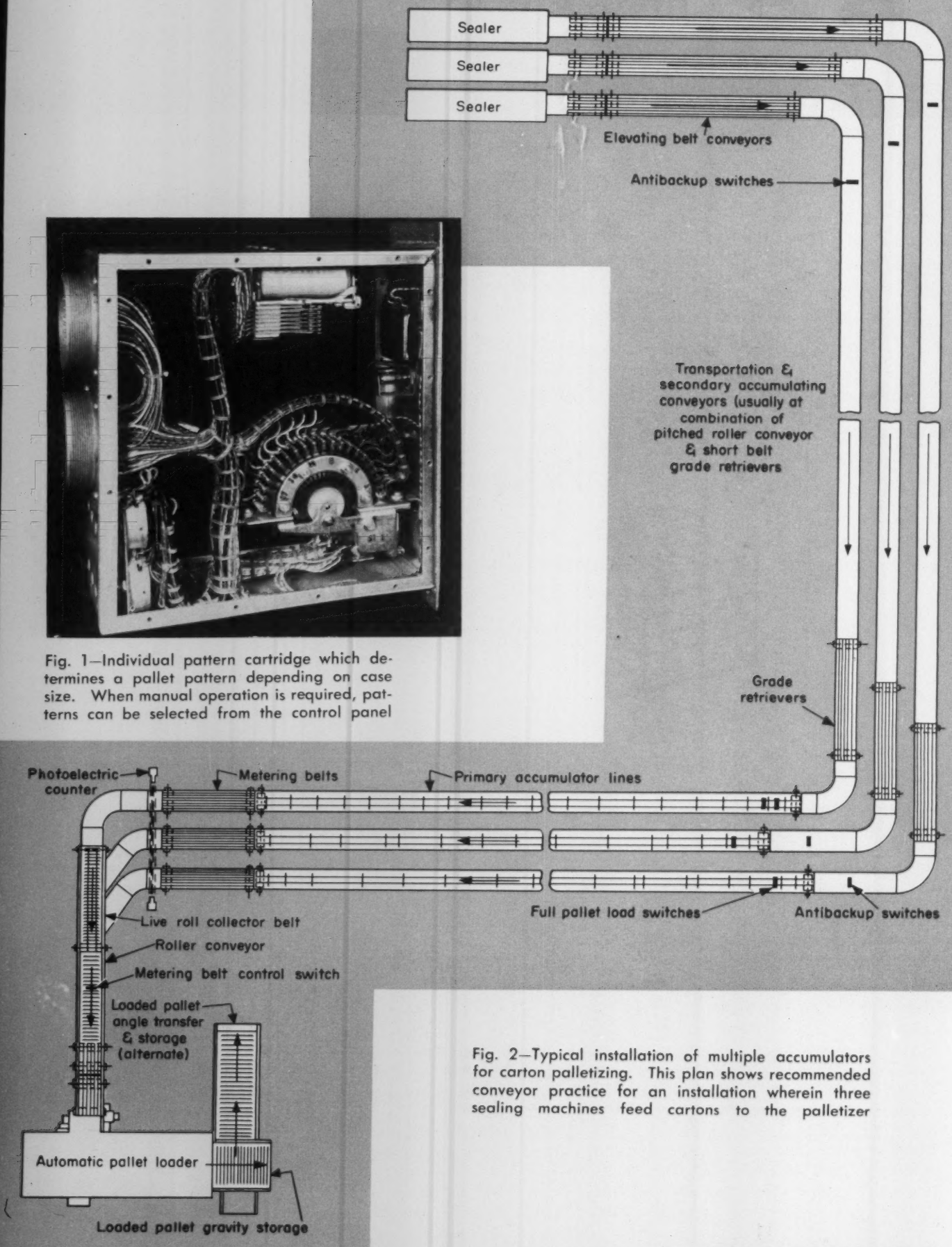


Fig. 2—Typical installation of multiple accumulators for carton palletizing. This plan shows recommended conveyor practice for an installation wherein three sealing machines feed cartons to the palletizer

Integration With The Line

In order to use an automatic pallet loader efficiently for different size cartons, the conveying system between carton sealing machines and loader, *Fig.* 2, must be designed to feed uninterrupted groups of cartons automatically. Cartons leave the sealing machines, each of which seals a different size case, and feed onto elevating belt conveyors. Discharge from these belts onto the roller conveyor transportation and accumulating system takes cartons to full-pallet load switches which signal the loader control system when a full-pallet quantity is ready. Antibackup switches provide back protection and stop elevating belts or grade retrievers should the accumulating conveyors become filled "upstream" of the full-pallet load switches. Grade retrievers are located to prevent accumulation on curves where blocks would occur.

Primary accumulator lines, long enough to accommodate the number of cartons required for a pallet load, are powered to provide controlled positive feed onto metering belts. From the full-pallet switch signal, the selector control determines the next line to be run and starts the applicable metering belt. This line is stopped by the photoelectric eye after counting the number of cartons needed for a full pallet.

A live-roll collector belt receives cartons from roller spur sections and delivers them onto a short, pitched roller, accumulating conveyor. Metering belts discharge cartons at a rate in excess of loader capacity to insure continuous operation. Metering belt control switch effects a stop and start action to compensate for these different rates of flow. Cartons are stacked by the loader according to the pattern cartridge corresponding to case size.

A typical analysis shows that considerable savings can be experienced even at low rates of production. Comparison of manual palletizing cost with pallet loader operation, *Fig.* 3, shows that one user made an annual saving of $18,805 at a production rate of only 15 cartons per minute. These figures were composites of production and cost factors such as labor, time, rate, volume, tonnage, depreciation, maintenance insurance and other variables that enter production cost analysis.

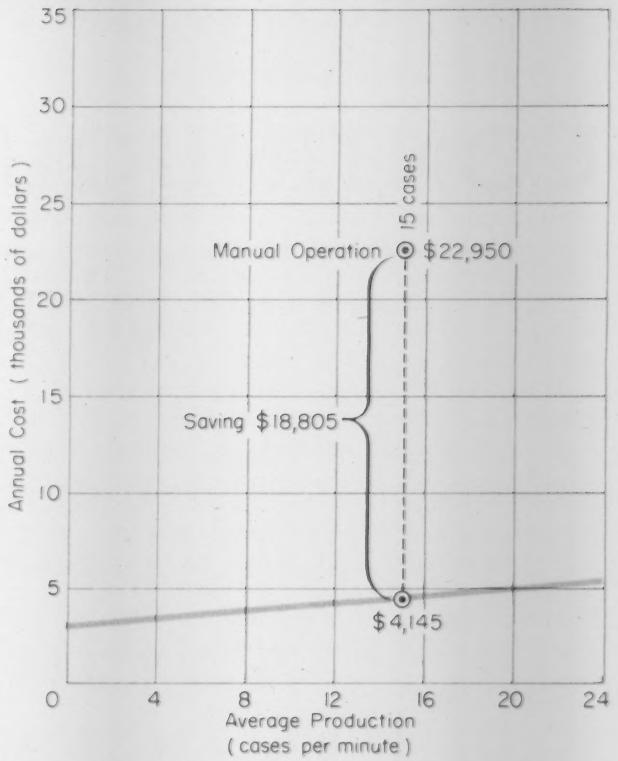


Fig. 3—Comparison between manual and automatic pallet loader operation. Cost of automatic operation at zero cases per minute represents depreciation and insurance

CONTINUOUS WEIGHT INSPECTION

BY ELECTRONIC BALANCE MEASUREMENT

Accurate, high-speed weighing of coins is accomplished by a clever series of handling operations, grouped around a flywheel that compares the unknown weight to a standard by measuring rotating unbalance created. The weighing principle is simple, but the system design is ingenious

AUTOMATIC INSPECTION for weight of individual pieces must be geared to the pace of production operations. Application of automatic features to the analytical balance principle is one means of accomplishing such inspection but speed is limited when small tolerances are to be detected. This problem was faced by the Treasury Dept. in weighing of a high-volume product—coins.

Weighing system used by the Treasury consists of dropping the coin into a basket suspended from the beam of an analytical balance and allowing the beam to come to rest. The beam is then clamped and the coin ejected into either a "high" or a "low" chute, all taking about 4 seconds. Limitation on improving the response speed of the balance is the ratio between mass of the beam and the comparatively small differential mass of the coins, since the small mass will not accelerate the large mass rapidly.

To achieve higher speed without loss in accuracy, a fully automatic machine of completely different principle for weighing coins has been developed by the National Bureau of Standards at the request of the Dept. of the Treasury. The NBS machine can weigh and sort 18,000 coins per hour within an accuracy of ¼ of the one per cent for 25-cent pieces and with even greater accuracy for larger coins. This system has advantages of high sensitivity, low susceptibility to seismic noise, and independence of physical properties other than diameter, which is held to extremely close tolerances in manufacture. The machine is much faster than the automatically fed analytical beam balance now in use at the Mints.

Weight Difference Causes Unbalance

Bureau's machine, *Fig.* 1, weighs coins by measuring the degree of unbalance imparted to a rapidly-revolving flywheel into which two coins, the standard and the one to be weighed, have been placed. If the flywheel is precisely balanced initially, the difference in weight between the two coins will displace the center of gravity slightly from the geometric center of the wheel. Detection of this displacement provides the basis for

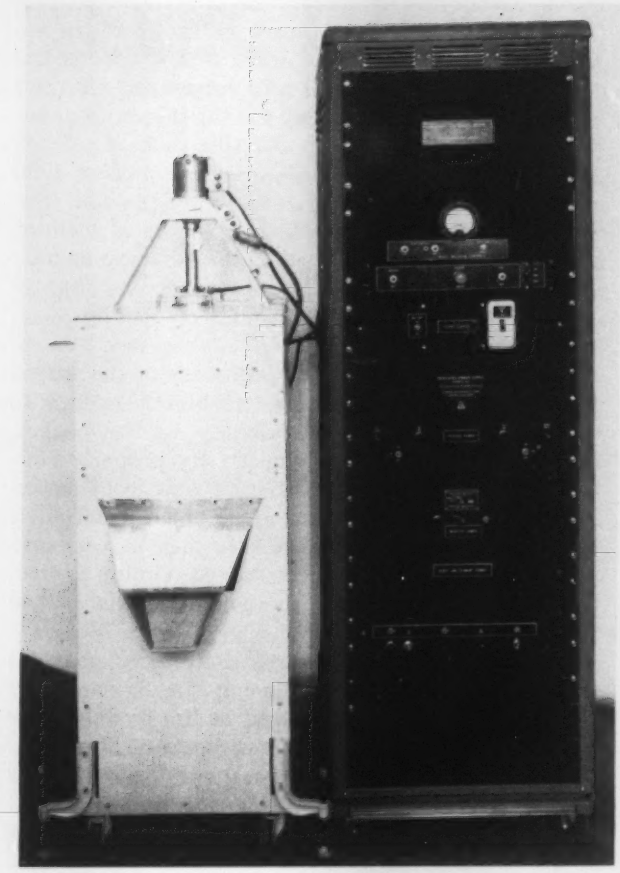


Fig. 1—Coin weighing machine developed by the National Bureau of Standards for the Treasury Dept. Cabinet at left contains the flywheel in which coins are placed for weighing. Weighed coins drop from hopper in front or back, depending on whether accepted or rejected. Cabinet at right contains the control circuitry and the power supplies

measuring weight of the coin. A method has also been developed for injection into the rapidly-moving flywheel and removing the coin after it has been weighed. Sorting of coins into light and heavy categories is accomplished through suitable circuitry which determines precisely the angular position of the wheel at which the coin is to be removed so that it will fall in the proper container.

Essentially, the system is a pendulum whose principal mass is concentrated in a flywheel, approximately seven inches in diameter, mounted at the lower end of a vertical rotating shaft, *Fig.* 2. At the top of the shaft, a gimble mount serves as fulcrum, and the dc motor which turns the weighing wheel is above. The pendulum is of such length that its natural period is much longer than the period of vibration established by the revolving wheel. Thus, vibrational effects of the wheel are independent of any resonant effect of the pendulum and rotation of the center of gravity of the wheel about its geometric center takes place as though the wheel were a body revolving in free space.

By rotating at 3000 rpm with coins about 2½ inches from the center of the wheel, an acceleration of nearly 500 g in imparted to the coins, magnifying any small weight differential 500 fold. Vector product of the large acceleration and the small differential mass is the force which causes the wheel to accelerate rapidly into a new orbit about its new center of gravity whenever a coin of other than standard weight is placed in the wheel.

Within six revolutions, the initial transient disturbance resulting from loading of a new coin into the periphery of the rotating wheel is damped. Since the wheel is revolving at 3000 rpm, these six revolutions take only 0.12-second. Subsequent detection of the constant amplitude of vibration determining the difference in weight between the two coins is made during the two following revolutions. A total of ten revolutions is allowed for the complete weighing cycle; thus, five coins can be weighed each second.

Electronic Detector

An electronic mutual-inductance micrometer probe placed near the wheel hub detects vibration of the pendulum shaft. This device is an extremely sensitive transducer which can determine a change in length as small as 50 microinches and can accurately measure the few thou-

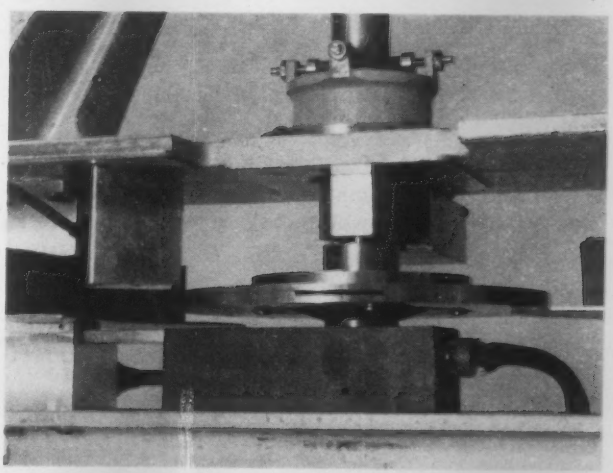


Fig. 2—Flywheel suspended from the lower end of the rotating shaft shows the coin slot in the edge of the wheel. Immediately below the wheel is the coin inserting mechanism which injects the coin vertically upward into the hub. Above the wheel, to the rear, is the mutual-inductance micrometer which detects and measures the amount of vibration in the wheel caused by the differential weight between the coin and the standard weight. The housing at the left contains a stroboscopic light used in balancing the wheel dynamically

sandths of an inch displacement in the weight-indicating vibration. The transducer consists of two coplanar, coaxial coils wound on a dielectric core. The primary coil is energized by a regulated frequency much higher than the wheel vibration frequency. The mutual-inductive coupling between the primary and secondary varies as a nearby conducting material—the wheel hub—moves toward or away from the coil assembly. When the wheel vibrates, the secondary coil generates a modulated ac signal whose period is equal to that of one revolution of the wheel. The transducer, with its regulated power supply and simple amplifier, produces a signal of relatively large amplitude which is linearly proportional to the departure of the coin from the nominal weight. Response speed is more than adequate to meet the requirements of this application.

Both the coin to be weighed and the standard coin lie on a straight line which passes through the geometric center of the wheel. If a coin is heavier or lighter than standard, the pendulum center of gravity moves along this line to one side or other of the geometric center. Thus, the wheel can vibrate in either of two modes which are 180 degrees apart with respect to the time at which the coin in the wheel passes a given point. A mirror mounted on the rotating shaft reflects a beam of light to a photocell, thereby generating an electrical pulse each time the coin passes a given point. The photocell signal coincides with either a positive or a negative signal from the transducer once during each revolution of the wheel, and combination of the two signals indicates whether a coin is heavier or lighter than the standard.

▶ Coin Feed Combined with Sorting

Injecting a new coin into the rapidly-moving flywheel and at the same time removing the coin that has already been weighed is accomplished by a novel method. The coin is initially inserted into the wheel by a polyiron-core solenoid which injects the coin vertically upward into a hole in the bottom of the hub. A 20 mfd condenser, charged to 800 volts, supplies energy for the injecting pulse. When applied to the solenoid, this pulse produces a powerful eddy-current magnetic repulsion field between the coin and the core, lifting the coin into the hole. Axis of the hole in the hub is inclined at a small angle to the axis of the rotating spindle and directs the coin into a position that is slightly away from the geometric center of the flywheel. Thereafter, centrifugal force causes the coin to move into the pocket at the periphery of the wheel, *Fig.* 3. A new coin imparts its kinetic energy to the weighed coin that is already in the pocket, forcing this coin off the wheel. By properly controlling the time at which the new coin is inserted into the wheel, the eject phase position is so selected that the weighed coin may be cast into an "accept" or "reject" receptacle. Timing is electronically determined by the weight of the coin in the wheel.

Simple addition to electronic circuitry provides means of dynamically balancing the flywheel. If two standard coins are placed in the flywheel, the only source of vibration is unbalance of the wheel itself. The mutual-inductance micrometer detects this unbalance, and a photocell energized by a light beam reflected from a mirror on the shaft assists in determining the phase of unbalance. Electronic combination of these two signals operates a stroboscope which illuminates only the heavy portion of the wheel. Degree markings on the edge of the wheel identify the heavy position, and set-screw adjustments on the periphery permit alteration of the weight distribution. Usually only one or two trials are necessary to restore the wheel to precise balance.

Undoubtedly, similar systems can be devised to weigh other individual pieces at high speed. If general requirements of shape and size uniformly are met, ideas applied by the Bureau of Standards can be adapted directly.

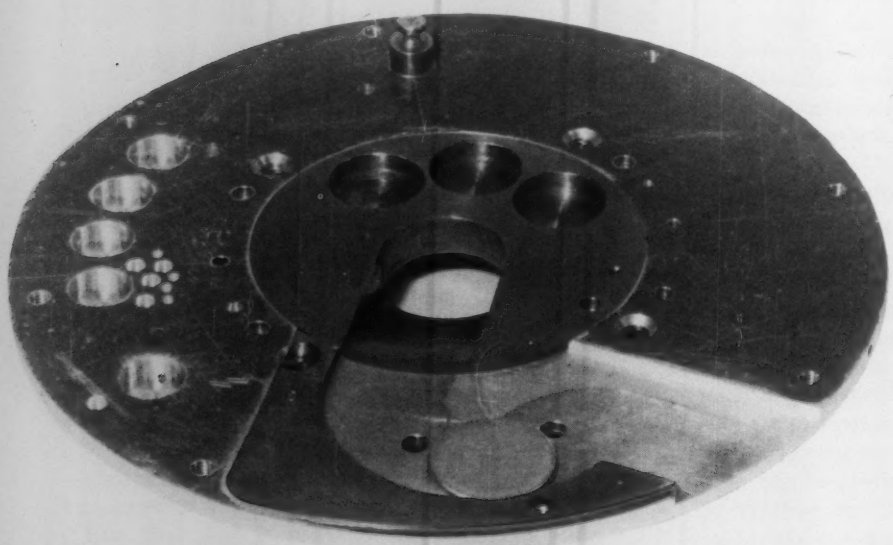
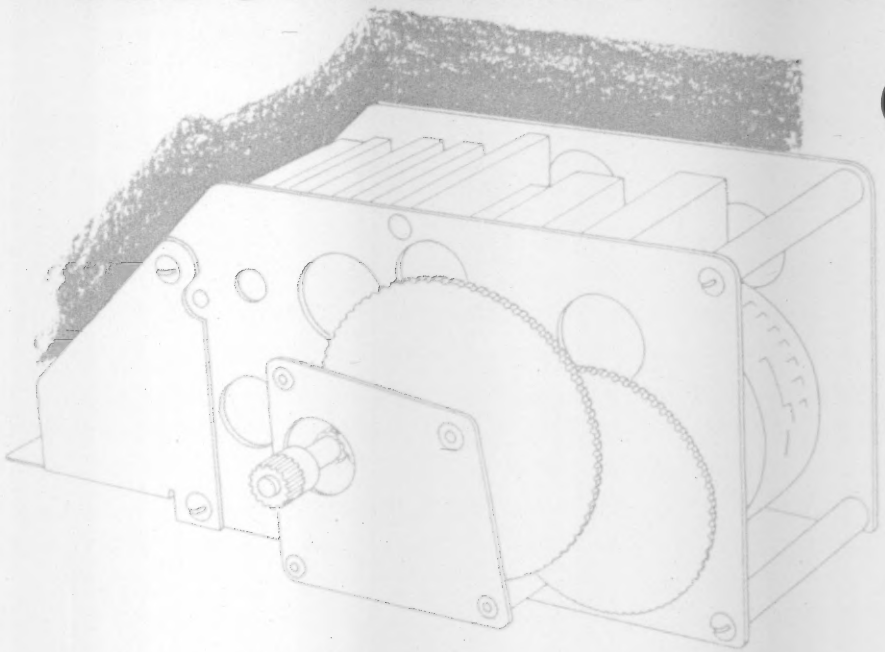


Fig. 3—Coin-weighing flywheel with the top cover removed. Coin is inserted into the hub from below and centrifugal force moves it to the edge. When a new coin reaches the holding pocket at the edge of the wheel, it imparts its momentum to the coin that is already there, forcing the weighed coin off the wheel. Diametrically opposite the wheel is the standard weight against which the coin is compared. Holes in the wheel at left are for dynamic balance

ELECTROMECHANICAL CODER



By ROBERT K. STERN
Division Manager
Fischer & Porter Co.,
Hatboro, Pa.

CONVERTS DATA FOR PROCESSING

Most automatic measuring devices use the analogous quantities of rotation or voltage to represent the quantity measured. When converted automatically, these analog data can be used advantageously as input for digital data processing equipment

KEY DEVICES in the development of automation are those that eliminate manual handling between successive automatic operations. Parallels in the area of data processing are the converters used to change representative signals from those of one system to another. Future universal acceptance of both analog or digital systems is assured by modern analog to digital and digital to analog converters, requirements being that these converters are fast, accurate, dependable, and economical.

Conversion of sensing device analog output from flow meters, thermocouples, pressure tranducers, and the like, into digital signals might be considered an automated link between factory and office. Digital signals are the required input to electric typwriters, digital computers, punched card equipment, and other data handling systems. The Digi-Coder, *Fig.* 1, now a product of Fischer and Porter Co., converts either mechanical motion delivered to its input shaft, or analog voltage input, into digital signals. Mechanical torque requirements are less than 0.20 oz-in. and minimum electrical signal less than one millivolt. Various models within the mechanical or electrical input types make possible any analog to digital conversion requirement including dynamic or static readout, linear or non-linear conversion, and direct reading.

Although the converter uses the binary number system as the basic conversion medium, both decimal code output for electric typewriters or IBM equipment, and binary code output for computers are possible. In addition, teletype, binary-decimal, or other special output codes may be furnished, *Fig.* 2.

Conversion is accomplished by mechanical means without relatively complex and costly electronic circuitry. Coded drums, driven by the input shaft, provide means for output digits. The first drum is driven directly by the input shaft; succeeding

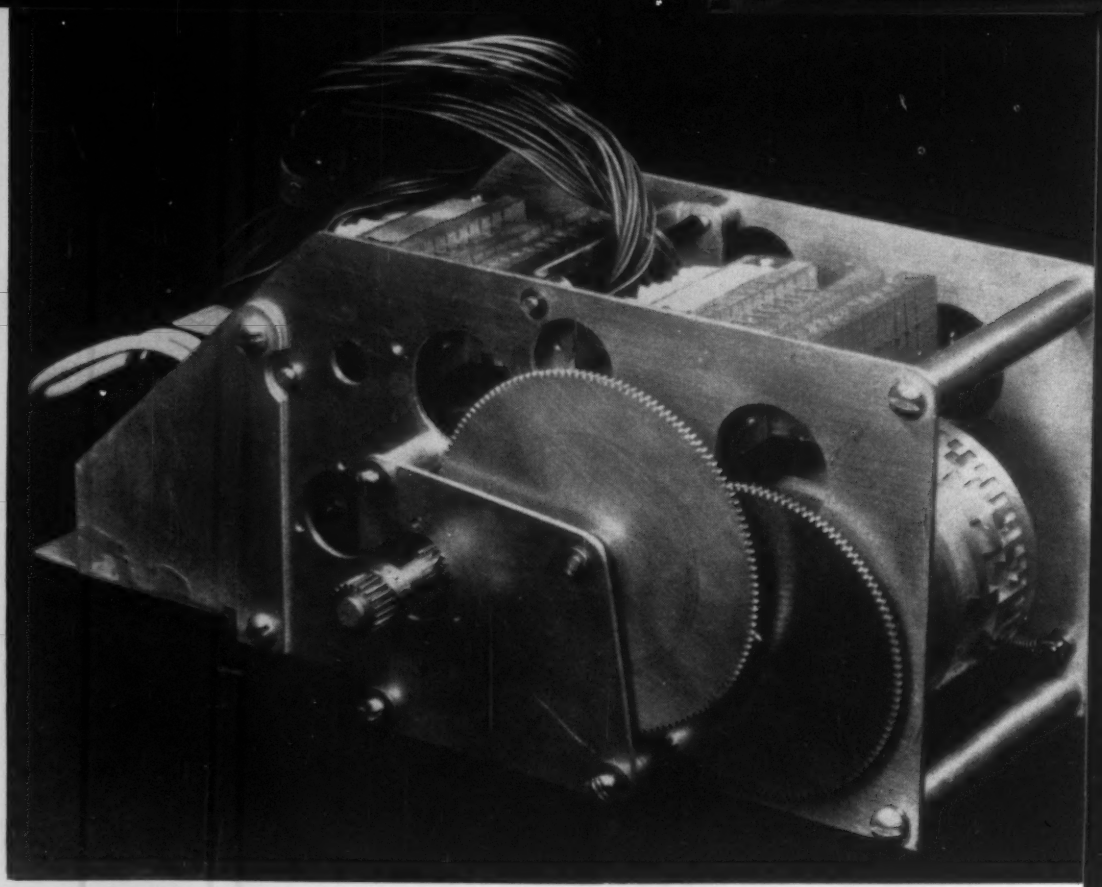
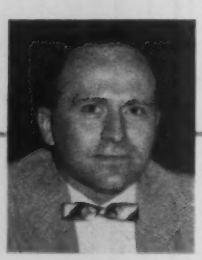


Fig. 1—Analog to digital converter containing a two-drum train. Input delivered to drive shaft rotates coded drums. Feelers, upon automatic or manual signal, drop onto drums contacting projections of the coded drum surface, closing an electrical contact. Combination of closed contacts represents the output code for a specific position of the input shaft thus converting analog input to digital output



THE AUTHOR

Robert K. Stern, 31-year old manager of the Data Reduction and Automation Div. of Fischer & Porter Co. is an electrical engineering graduate of Long Island University and RCA Institute. After two and one-half years in the Marine Corps, Stern joined the Crouse-Hinds Co. as product engineer participating in development of equipment for the refinery and process industries. In 1952 he founded the Electrical Development Co. Inc. for development and manufacture of industrial data reduction equipment. This company in its two years of existence perfected the Digi-Coder and other data reduction components suitable for industrial application. In February 1954, the company and its manufacturing subsidiary, the Digi-Coder Corp., became the Data Reduction and Automation Div. of Fischer & Porter Co. with Stern as manager.

drums are driven through reduction gearing by the previous drum. Each drum has a series of circumferential hills and valleys and a set of mechanical feelers. These hills and valleys make use of the "yes-no" binary counting system since the output signal occurs when feelers come in contact with hills of the coded drum surface.

▶ Number Systems

In the binary system, only two characters are used, 0 and 1, or on and off, contact and no contact. Starting with 1 of the binary being equivalent to 1 of the decimal system, the binary system increases by doubling in value each time the digit 1 is moved one position to the left. Hence, 2 of the decimal system has a binary equivalent of 10, the equivalent of 3 is 11, of 4 is 100, and so on.

As an example, a Digi-Coder with a binary-decimal output code would have the first drum represent units and tens digits, providing one hundred counts per revolution. Each drum has eight coded wheels, four per digit (1-2-4-8 of the binary system). During readout, the input shaft is stopped and the readout solenoid actuated, bringing the feelers down into contact with the hill portions of their respective code wheels and producing a digital signal represented by a discrete contact position.

In order that ambiguous readings are not obtained, such as 9299 or 9100 when increasing or decreasing between 9199 and 9200, mechanical

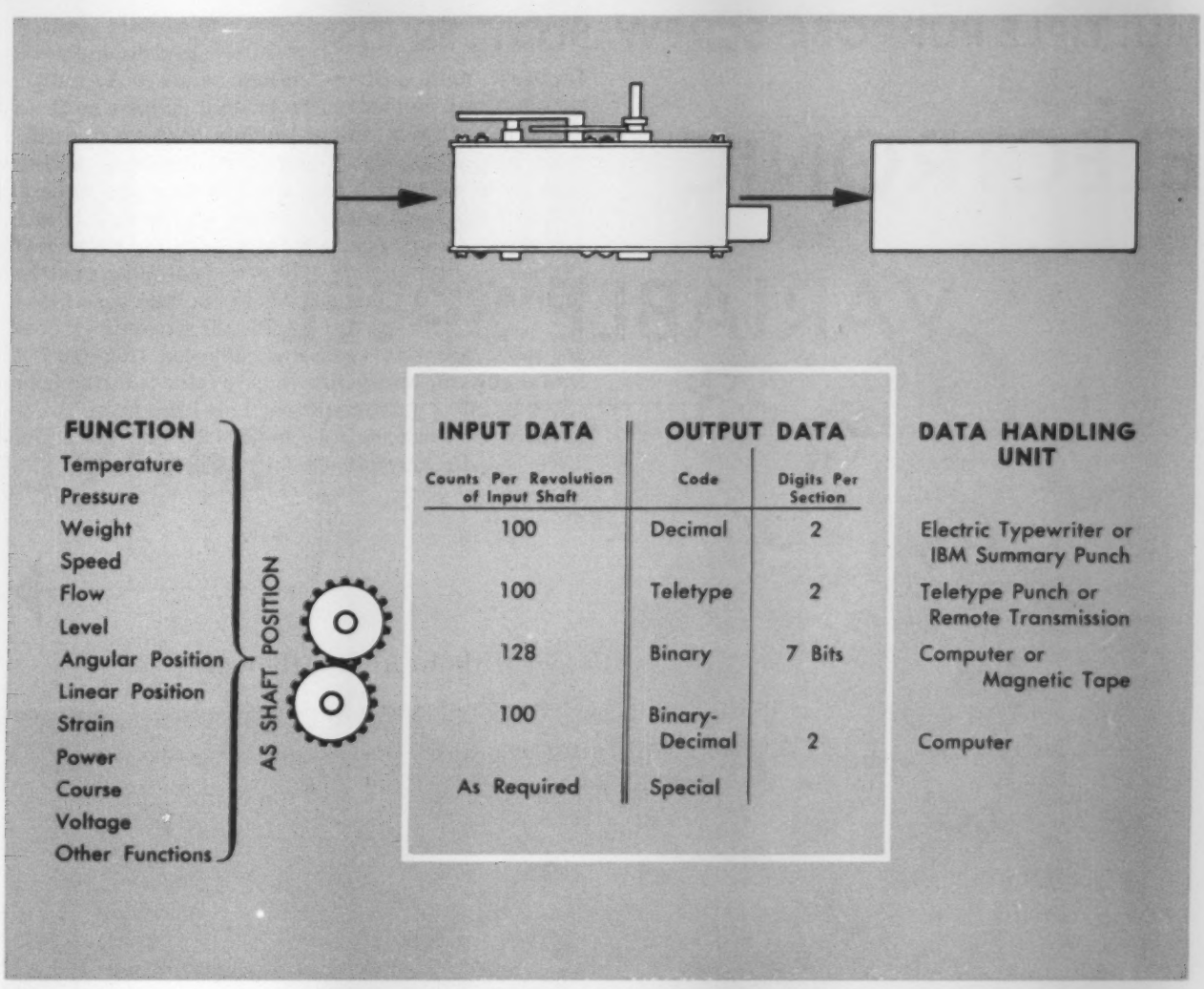


Fig. 2—Magnitude of temperature, pressure, weight, voltage, or any measurable function may be transformed into shaft position through a self-balancing potentiometer. The Digi-Coder converts this shaft position to discrete electrical contact positions for use with digital data processing equipment

feelers must transfer to their next position at the same instant that the adjacent drum passes through the zero position. This is done mechanically through a spiral cam and automatically makes the proper selection of position for an unambiguous reading. Readout does not depend on exact positioning of drums through the gear train but on positioning of feeler assemblies. In a five-drum train, the last drum moves as little as 0.1×10^{-9} revolution.

▶ Present and Future Applications

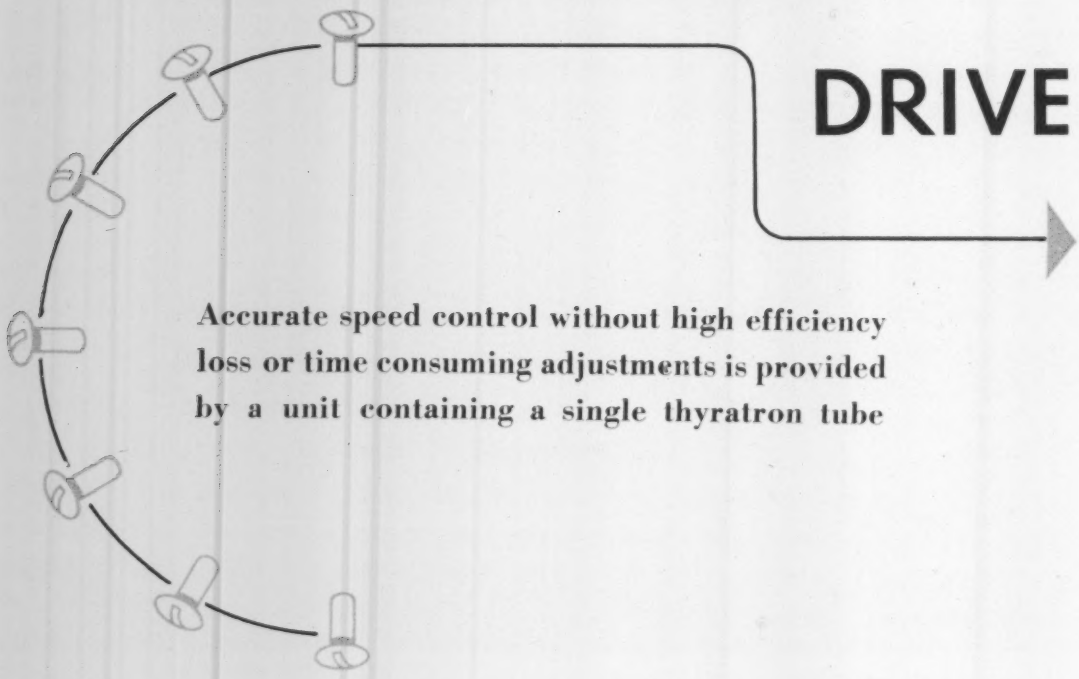
In addition to process industry applications, the Digi-Coder is used by General Electric with a high-speed temperature scanner to record 200 temperatures per minute, by an Air Force development center to digitalize output of conventional instrumentation for direct input to digital computers, and by Tinius Olsen to digitalize output of test balance equipment.

Similar devices which can convert from digital to analog are likely to be more useful in affording simplified control in the factory. It is possible to type a production schedule on a tape-punching typewriter and produce an analog output by running the tape through a digital to analog converter, creating the means to actuate and control. Such systems are being considered in controlling production of sensitized paper, continuous inventory control in steel mills, and the automatic adjustment of processes to change type and quality of adhesive tapes to meet production schedules.

Converters provide a step toward elimination of all visible information except that which is significant at any given instant and requires personal decision and action. The task of data processing is not to think in a human sense, but to organize and present facts for management and supervisory thinking. Data processing machines such as the code converters relieve the brain of monotonous operations and free it for exercise of intelligence, discretion, and judgment.

MULTIPLE-PURPOSE SCREW SLOTTER USES

ELECTRONIC VARIABLE SPEED DRIVE



Accurate speed control without high efficiency loss or time consuming adjustments is provided by a unit containing a single thyratron tube

WHILE FULLY AUTOMATIC pushbutton factories are still in the future and the idea never will be applicable to all plants, adjustable speed controls with wide range are helping to bring the principles of automation to many industries. A screw slotter, recently developed by Gros-ite Mfg. Co. Inc. of Hartford, is an example of speed control applied to today's production tools. Versatility and adaptability realized are typical of much equipment that will be the basis of tomorrow's automatic factory.

In designing the screw slotter, a machine was desired that would handle wood, sheet metal, and machine screws made from brass, steel or stainless. For each type of material there is, of course, an optimum cutting speed and feed. This machine is designed to take advantage of two variable-speed drives, one to drive the hopper and feed mechanism and the other to power the cutter wheel.

Screw blanks are placed in a hopper on top of the machine, *Fig.* 1, from which they are automatically fed into slots on the rim of a large wheel, screw heads protruding. Most desirable speed of this wheel for the work at hand is preset by the operator. Screw heads advance, one at a time, to the cutting position where a cutter wheel performs the slotting operation. The speed selector switch for the screw holding wheel can be set for most efficient operation at speeds of 1½, 3, 4½ and 6 rpm and also has a jog position for setup purposes. After clearing the cutting wheel, screw heads are completely deburred and drop into a work basket at the front of the machine.

The cutter wheel operates at 200, 400, 500 and 600 rpm, operator controlled, and is completely independent of the drive powering the hopper and feed mechanisms. Sixteen combinations of speeds and feeds are available without it being necessary to stop the machine.

Drive and Control Elements

Two Arrow-Hart & Hegeman electronic variable-speed drives are used, one driving the cutter wheel, the other powering hopper and feed mechanisms. Each drive consists of a single point push-pull selector switch, a specially wound series motor, and the control package, *Fig.* 2. Single-phase, 60-cycle ac source is rectified to dc by a single tube, half-wave rectifier, controlled by a static phase shifter, *Fig.* 3. Direct current from the control is fed into a fractional-horsepower series motor, (maximum

¾ hp), instead of a shunt motor as used in many electronic drives.

Use of a series motor provides high speed at medium torque, high starting torque, and requires less current than a shunt motor, resulting in lower output demand from the single thyratron tube used in the control. When desired, this speed control can provide a stepless range from 100 to 3,500 rpm with a dual-range feature. Speed variations with varying loads are held substantially constant, rapid acceleration is possible, and control can start, stop or dynamically brake the motor.

Push-pull selector switches take the place of pushbuttons, relays, and contactors, provide a single-point control and permit moving from any position on the dial to any other position without activating any of the intervening circuits.

Fig. 1—Screw slotting machine with variable speed control, lower right corner, allowing the machine to handle wood, sheet metal, and machine screws at optimum speeds. Two push-pull selector switches are shown, one actuating the feed control, the other, the cutter wheel

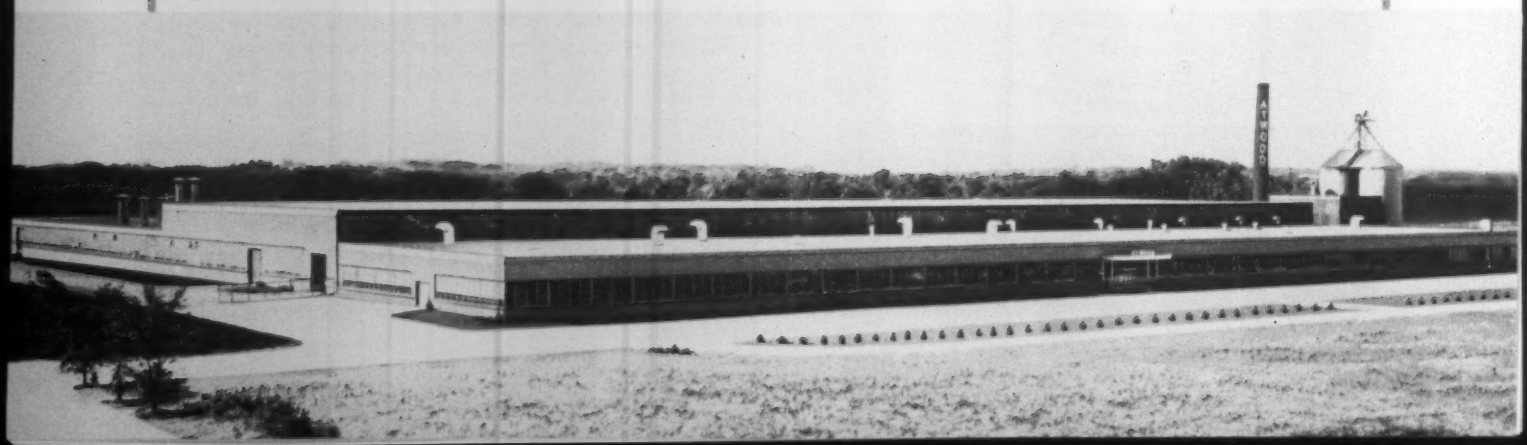
Fig. 2—Control elements showing single thyratron long-life tube. Plastic covered parts are "plug-in" replaceable units

Job-Shop Automation

Industrial manufacturers whose total production volume consists of relatively small quantities of a large number of different products are as interested in reaping the advantages of automation as are the enterprises that "make 'em by the millions." This type of production is called by many names: intermittent lot, short run, small quantity, job shop, diversified, etc.; but all are concerned with utilizing the existing plant facilities to make a variety of items rather than continuous long-term repetitive production of the same product.

Some techniques of automation are certainly applicable to any type of production, but large single-purpose special machinery generally needs large volume runs to pay off its investment and make its purchase economically sound. Where the dollar value of sales of a given item is small, other approaches to the problem of productivity must be sought: multipurpose machinery, interchangeable tooling, combined operations on similar phases of different parts, and pushbutton operated automatic cycling machines are some of the considerations that influence this type of production planning.

Here in an article based on a talk presented at the Annual Meeting of the ASME in New York in December 1953, a manufacturer of diversified products tells how his company took its first steps toward automation by establishing a plant layout with flexible production lines as a cornerstone upon which to build savings by automatic handling.



STEPS TO JOB-SHOP AUTOMATION

LAYOUT FOR HANDLING

By SETH G. ATWOOD
Executive Vice President
Atwood Vacuum Machine Co.
Rockford, Ill.

THIS IS WHAT the Harvard Business School would call a case study. It is a case study of the steps taken in our company to get ready for future steps that might be taken to mechanize or automate our operations.

Frame of Reference

First of all, this is a so-called job shop. Primary overall objectives which must be kept in mind are: (1) To retain flexibility and (2) lower costs. The problems faced are in essence more or less common to job shops and these steps taken to lower costs and yet retain flexibility probably cannot be used by others without some modification.

The products made are primarily pressed metal assemblies. These assemblies are, generally speaking, stamped and machined parts that vary from small washers up to 3/8-inch thick metal 2 feet square which has been drawn. We are currently shipping under 500 different assembly numbers. Generally speaking, there will be an average of four parts to an assembly. Therefore a total of 2000 products are actively processed through the plant each month. From a facility point of view, 17 acres of plant space are utilized, something over a thousand different machine tools, including presses, mills, drills, welding, grinding, heat treating, plating, painting and, of course, the necessary tooling and engineering for this production. This plant has approximately 1000 employees.

Fig. 1—View of new plant, laid out for diversified production with automation in mind

Where are Savings?

In this business, there is little opportunity to lower costs through lowered material costs in view of the fact that we are buying primarily basic mill steel in mill quantities. It certainly cannot be overlooked that savings are important and can be realized through more efficient tooling; in fact, much in the way of savings is accomplished in job shops in the development of progressive dies and other tooling refinements to increase production and reduce direct labor, and yet use standard machines and equipment in producing the parts.

In analyzing our financial data, it seemed clear that the biggest saving area is clearly in reduced direct labor. On the assumption that further tooling refinements can and should receive continued study to reduce direct labor, the question was asked, "What essentially does labor do?" The answer as far as we are concerned is that it moves material in and out of machines, between machines, from raw stock into production, and from finished parts into assembly and then into shipping. It seemed clear that this assumption was correct when it was calculated that 1000 employees who work here had of necessity to move over 4 million pounds of material a day. Essentially the machines and tools cut and form the parts. In view of these facts, therefore, automation to us essentially means mechanized material handling to reduce labor.

Elements of Job Shop Problems

Without going into any particular detail on the previous plant layout, prior to constructing a new

building a year and a half ago, it will suffice to say that it was a traditional departmental layout. The machines were grouped by type in departments. Because of the number of machines involved, there was a substantial travel distance between departments. Due to the variation in operations sequence of the production processes, material movement was at a maximum. A job shop departmental layout provides advantages:

1. Supposedly the only logical arrangement in view of the variation in piece part and operation sequence.
2. A simple control of labor and equipment.
3. A simple labor and overhead cost control center.
4. Supervisory specialists.

Some major disadvantages exist, however:

1. The maximum movement of work in process is required.
2. Scheduling is difficult and there is a poor work flow.
3. Supervisory friction.
4. Poor space utilization and a lack of flexibility.
5. Expansion difficulties.
6. Productive labor quality is perhaps higher than necessary.
7. Automation ideas as they relate to mechanically transferring material between operations are not practical.

To eliminate the above listed disadvantages of a departmental layout became our objective.

▶ Working Toward the Objective

Over 10,000 planning hours went into the design of a flexible plant and the layout of equipment in the plant. In order to assist, use was made of accurate scale models of equipment and in some cases, such as a determination of certain material handling ideas, full scale tests were conducted. It became immediately clear that to achieve and retain flexibility and to set up production lines as proposed, a new building would be required, *Fig.* 1.

This new building has a minimum of fixed obstructions. In fact, with the exception of the two electrical and air distribution centers and the more or less fixed nature of the plating equipment, all other equipment may be relocated if necessary, with a minimum of difficulty. Lighting levels can be immediately changed by plug-in electrical outlets; machinery can be moved because of the arrangement of the air and electrical lines; and the areas containing the larger machines are serviced with overhead cranes. Machinery located in areas not serviced by overhead cranes can be moved by large fork trucks.

The north, west and south walls of the plant are fixed and the plant is designed for expansion to the east, where a substantial expansion acreage is available.

If you were to visit this plant, a word of explanation on the layout would be worthwhile before a tour through it was made, in view of the fact that the machines seem to be mixed more or less without reason. The job shop production lines, *Fig.* 2, were determined and laid out on the

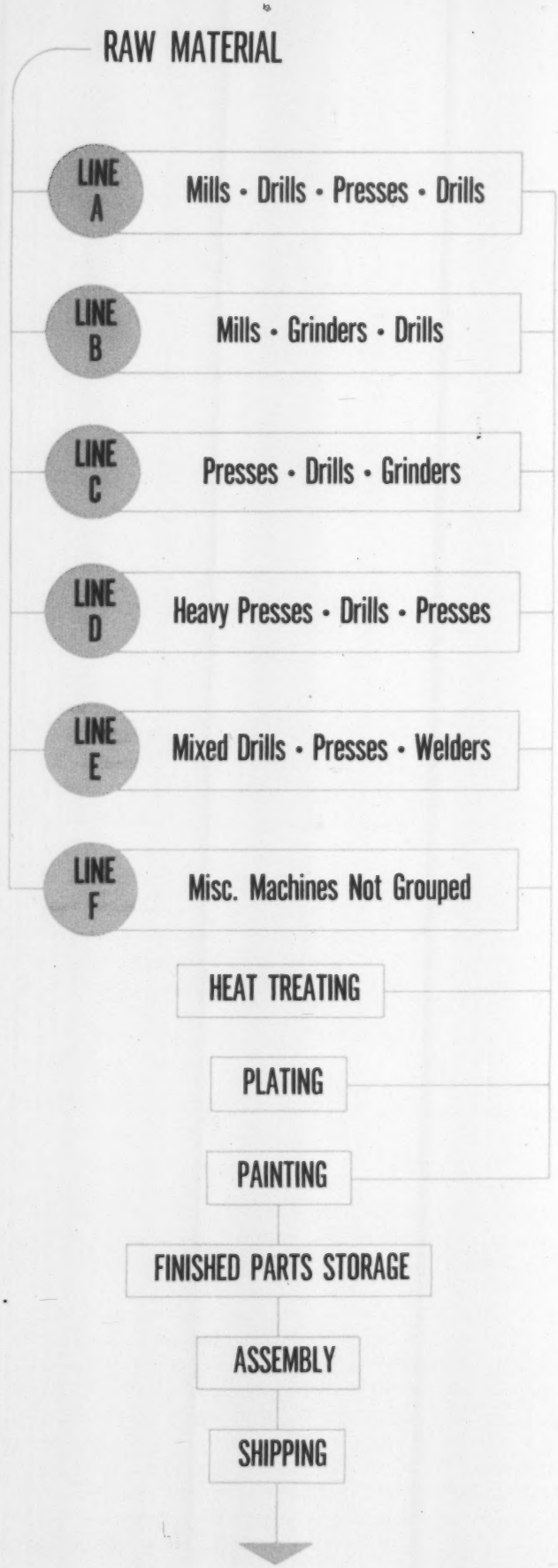


Fig. 2—Chart of production lines arranged by production process sequence of parts manufacture

following basis. Determining the number of lines:

1. Make a card for each active manufactured part, and record the manufacturing operation sequence on this card.
2. Sort these parts cards by grouping like operation sequences to determine the number of production lines. Punched cards are used in doing this job and are visually examined for the number of parts falling within a like operation sequence group, to arrive at a judgment of how many lines should be established. Each of the lines will process 2 to 500 parts. Line *F* in effect is a catch-all for nonconforming parts.

Determining the number of machines in each line:

1. List the monthly experienced or anticipated volume of production for each part on the operation sequence card.
2. Determine the average monthly production rate of a machine for each type of operation.
3. Divide the total monthly volume of parts for each operation in each production line by the monthly machine production rate for that operation. The quotient obtained is the number of machines that is required for each operation in each production line.

The laying out of these flexible production lines may be the first step in a mechanization program for a job shop.

What of the Future?

Such a layout puts us in a position to consider further automation ideas. Because of a job shop's requirements for flexibility in production further improvements probably will not be along traditional lines of constructing special-purpose machines for producing a more or less standardized product in large volume. It is in this area, of course, that the greatest strides have been made in the past, in the automotive industry, in shell production plants and other high-volume standard product facilities.

It seems that there is another road that can be traveled as far as the job shop is concerned and that is to link together relatively standard

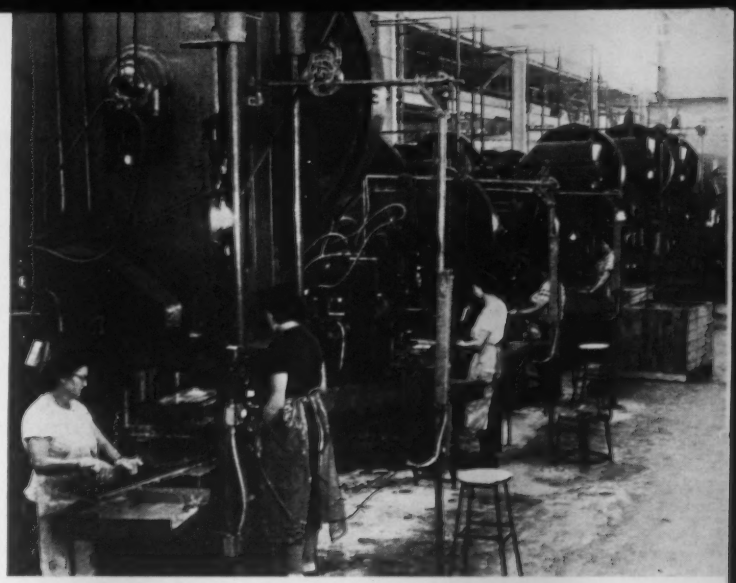


Fig. 3—Presses arranged in line use chutes to handle workpieces between operations

processes which are of a flexible nature in order to achieve greater economies in processing and handling. The first and integral part of this approach is, of course, to continuously improve dies and tooling for parts production; secondly, to evolve ways and means of starting, stopping, ejecting and inspecting work done by standard machines using these dies and tools; third, linking standard machines together by providing means for loading, unloading and conveying parts between the machines; and fourth, synchronizing these more or less standard elements which can be flexibly used to obtain an even flow of parts production.

There are students of this subject of automation who feel that in the long run this approach to automation will be more satisfactory because regardless of volume and attempts at standardization there is a risk of obsolescence which is uneconomic and inherent in the special-purpose machine approach. An excellent example of this thought (i.e. linking of common standard elements) is represented by the government's work

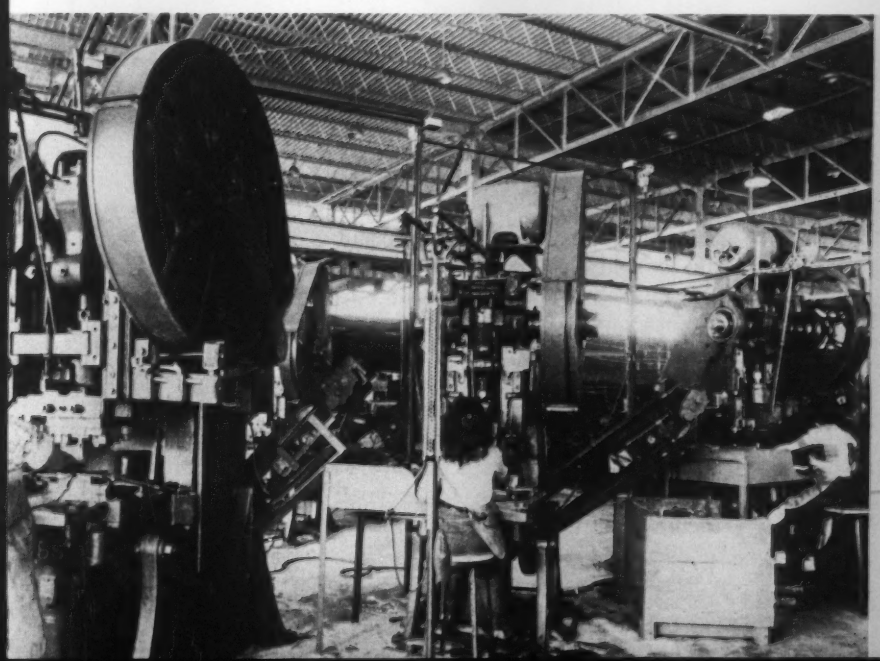


Fig. 4—Versatile belt conveyor units save handling time in job shop

in the field of electrical circuits and electronic products design experiments commonly referred to as Project Tinkertoy.

We have just begun to attempt some practical applications containing further improvements in material handling and processing as a result of our production line layout. In the case of one government item, without redesigning the product and without the procurement of special machinery, but through the improvement of tooling and the addition of a number of mechanical handling devices such as conveyors, chutes, overhead cranes, air ejection devices, and feed mechanisms, the labor involved was reduced from 42 people to 18 people and an equivalent volume of production is turned out. Under the old plant layout with the departmental basis, there were practically no conveyors or chutes between operations. Within the year that we have been in operation in the new plant, we have already added over 100 conveyors and chutes, *Fig.* 3. What has been done to date is certainly not new to a production line plant, but it is new to the job shop business which must continuously keep in mind the requirements for flexibility and variations in parts processing.

Automation in the Office

The subject for another complete study would, of course, be the problems that arise in the office and in paper work functions as they relate to mechanization in the factory and also what can be done in the office to reduce costs. Excluding engineering activities, the greatest costs in the office are related to doing the necessary paper work. Attempts to keep this paper work to a minimum have included such things as establishing a functional division called "Planning and Control," whose responsibility generally speaking is to perform all paper work for the organization. Secretaries have been eliminated and telephone-type dictation units are used. The planning division has the responsibility for taking the customer's order form and breaking it down into requirements from a time and volume point of view as far as production, purchasing, personnel, designing, tooling, and sample building are concerned. To further use this common information through punched cards or otherwise to keep control of inventories of purchase parts, raw material, work in process, and finished goods; to collect costs, process payroll, purchasing, accounts payable, and all the other clerical functions that can be logically, efficiently or effectively combined, so that the other divisions and division heads will be free to concentrate on the more important aspects of their work. Perhaps as a result of our efforts in this direction, combined with the fact that the whole organization is attuned to, or rather has an allergy toward, red tape and paper work; we have been able to keep the total of the supervisory and clerical personnel (which includes factory personnel in these capacities such as foremen, storeskeepers, etc., but excludes tool designers and research draftsmen) to less than 10 per cent of the total number of employees.

Problems in Making a Change

A word is in order with regard to putting into effect such a program of changeover as has been accomplished in both the shop and office. It was our experience that no matter how interesting the theory you have in mind may be, the most effective manner to sell the program is to adopt the tried and true method of selling it from the bottom up. We simply took the scale models of machinery, laid them out as best we could, and then called the production men themselves and asked them to work with us in following through certain parts to see how the layout would work. We didn't work in large groups and we let the ideas filter through without going into theoretical discussions.

Appraisal of Results

It is very difficult to factually appraise the success of this move. Products have changed, volume has materially increased, and dollar figures cannot be compared because of accounting changes. It is perfectly clear, however, that the average distance that material moves has been cut approximately 80 per cent. This has enabled a 50 per cent reduction in the number of people involved in internal trucking. In terms of mechanization, there is no longer anyone on the payroll who carries the job classification "hand trucker." Fork trucks, cranes, conveyors, (*Fig.* 4) chutes and elevating mechanisms are used to the exclusion of hand trucking as far as productive operations are concerned. It doesn't take any charts or tables to tell that the volume of production per square foot of floor space has been materially increased. Similarly the flow of work from raw material to finished part is smoother and much more easily accomplished in terms of follow-up effort. There has been a decided improvement as far as supervision is concerned in the sense that departmental buck-passing and friction has been largely eliminated.

We consider what has been done to be only a start in reducing costs and improving production methods, but that the opportunities for further improvement through a restudy of layout and the development of flexible mechanical handling means are now in hand. In a humorous vein, there is nothing to it: all that we had to do was build a new plant, sell the ideas that have been mentioned here to a few hundred people, reassign the foremen and other supervisors who stayed with us, develop a new production control system, new material handling methods, new cost accounting procedures, and do a little work in the meantime to make sure we weren't making a colossal boner.

Third of a series, AUTOMATION presents another section of the ASME standard "Automatic Control Terminology"; an original work of the Terminology Committee of the Industrial Instruments and Regulators Division. It is hoped these data sheets will assist in furthering the adoption of a standardized language in the field of automatic control

PROCESSES

THEIR ELEMENTS AND CHARACTERISTICS

THE CONTROLLED VARIABLE is a condition or characteristic of the CONTROLLED MEDIUM. For example, where temperature of water in a tank is automatically controlled, the controlled variable is temperature and the controlled medium is water. Also, the MANIPULATED VARIABLE is a condition or characteristic of the CONTROL AGENT. For example, when a final control element changes the fuel-gas flow to a burner, the manipulated variable is flow, and the control agent is fuel gas.

301. A PROCESS comprises the collective functions performed in and by the equipment in which a variable is to be controlled.

"Equipment", as embodied in this definition, should be understood not to include any automatic control equipment.
The process may also be referred to as the controlled system.

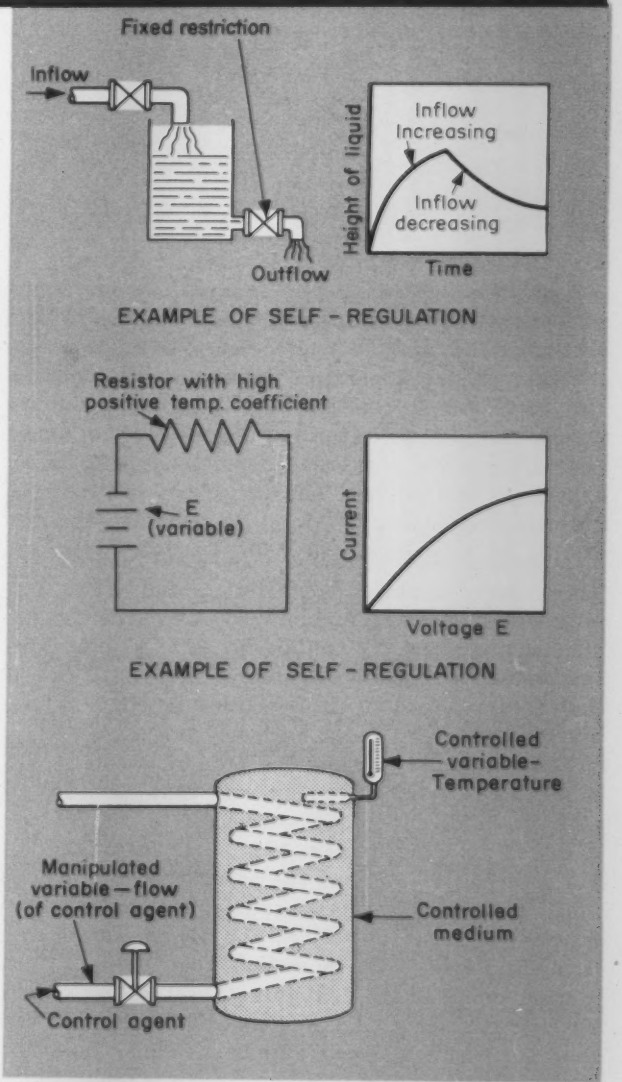
302. SELF-REGULATION is an inherent characteristic of the process which aids in limiting deviation of the controlled variable.

303. The CONTROLLED VARIABLE is that quantity or condition which is measured and controlled.

304. The CONTROLLED MEDIUM is that process energy or material in which a variable is controlled.

305. The MANIPULATED VARIABLE is that quantity or condition which is varied by the automatic controller so as to affect the value of the controlled variable.

306. The CONTROL AGENT is that process energy or material of which the manipulated variable is a condition or characteristic.



AUTOMATIC STAMPING

HIGHLIGHTS FEED SYSTEM

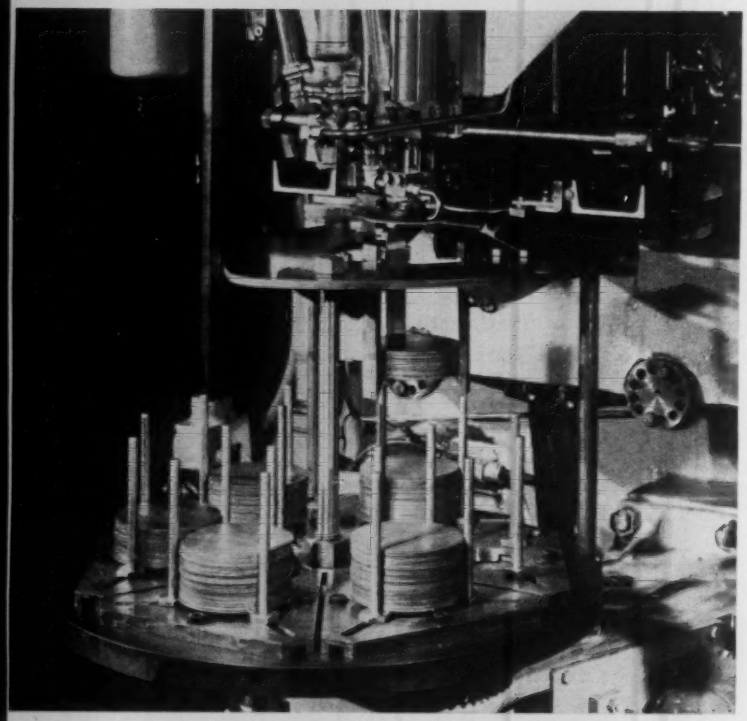


Fig. 1 (Left) — Vacuum cup shown holding a single blank at level of press bed. One load of blanks has been picked up from the six-station turret below. Gripping fingers take the blank from the vacuum cup to the press

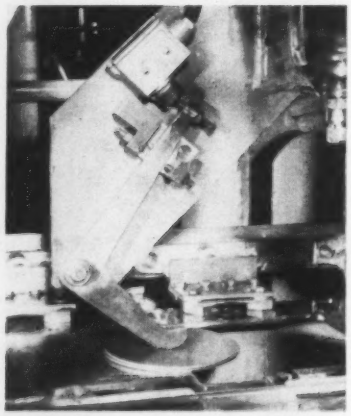


Fig. 2 (Above)—When two blanks stick together and feed into the press, they lift this feeler which actuates a limit switch and opens a solenoid operated trap door. Blanks fall through, the door closes, and the press operates uninterrupted

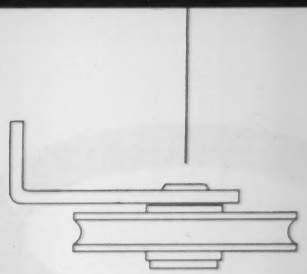
TRANSFER FEED principle in automatic presses was introduced over 60 years ago. These early presses had friction dial feeds and only five stations; they stamped gas burner shells, cone-shaped tops for containers and the like. An up-to-date version of these early presses has been delivered to Ford by E. W. Bliss Co. to stamp a starter brush end plate, formerly die cast.

The automatic transfer mechanism consists of a plunger with rubber vacuum cup that descends to pick up a precut blank and rises to deliver the blank to gripping fingers, *Fig.* 1. If the fingers do not receive a blank from the plunger, a limit switch stops the press. As the supply of blanks is exhausted, a limit switch at the lower end of the plunger stroke trips a switch that turns a six-station turret to the next full station of blanks and an elevator pushes a new stack of blanks into the feed position. If a new supply of blanks does not come into position, a limit switch stops the press.

Another limit switch in the transfer feed line prevents double blanks from reaching, and possibly ruining dies and damaging the press. If two blanks stick together they trip this switch and actuate a solenoid which opens a trap door *Fig.* 2. Both blanks fall through and the press continues uninterrupted.

Ford uses the 13-station press to make this end plate from 5-inch low carbon steel blanks, 0.090-inch thick. The press takes each blank, puts it through six successive draws, flanges it, burnishes a hole, restrikes the flange, pierces ten small holes, lances four locating tabs and trims the part to final diameter.

By feeding itself, checking and correcting misfeeds, performing 11 separate press operations, and by delivering up to 28 completed parts per minute, this press speeds up production and cuts the cost of manufacturing as compared to the die cast process.



AUTOMATIC ASSEMBLING FOR LOW-BUDGET JOBS

Used as primary power element automatic hydraulic presses combine with other basic components in low cost special machines which can be readily revised for changed requirements

By RALPH H. BEHREND
Manager C-Press Div.
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THE AUTHOR

RALPH H. BEHREND, manager C-Press Div. of the Hydraulic Press Mfg. Co. has been in charge of C-Press standardization and development at H-P-M since 1953. His background of engineering and tooling experience in former positions makes him an authority on press applications and production methods. Mr. Behrend is an engineering graduate of Fenn College of Cleveland, Ohio, and has had 36 years' engineering and executive experience in the tooling field. In 1918, he joined the Cleveland Automatic Machine Co. where he advanced from an apprentice in tool and die work to chief tool designer. Thereafter, he was on the engineering staff of Ohio Forge and Machine Co. of Cleveland, Ohio; chief tool engineer for the Chicago Pneumatic Tool Co. at Cleveland; a member of the engineering staff of Cleveland Equipment Works of General Electric; in charge of the special tool dept. of National Acme Co. at Cleveland; and general superintendent of Black and Decker Electric Co. of Kent, Ohio. Before joining H-P-M, he was superintendent of the Tooling Div. of Denison Engineering Co. of Columbus, Ohio, where he was in charge of designing attachments and tooling for all types of small press applications.

TWO IMPORTANT benefits emphasize the need for automation on many operations: the elimination of manual skill in the operation of machines and the elimination of material handling on the part of the operators. The first feature makes possible an automatic control of quality and the second provides the assurance of consistent machine output. These two advantages apply equally to all phases of manufacturing. When production is machine controlled the results are more consistent—whether it be a primary or secondary operation, subassembly, final assembly or inspection.

Use Standard Basic Components

The use of specialized equipment is limited in most cases to large runs in the mass producing industries. Automatic methods are sometimes out of the question for smaller runs because of their cost. This article deals with the use of standard components available from various manufacturers that can be applied to the problems of automation. The major advantage however is the unlimited use of these basic machines through retooling for other operations.

The C-frame hydraulic press can play an important part in many operations applying one or both of the above principles to the method of production.

LOW-BUDGET JOBS

The automatic control of hydraulics applied to work with unskilled labor produces great improvements in the output of assembly departments. Assembly work is a particular challenge to the production man and tool designer. Here, because every part is different in shape, size and material, real ingenuity must be forthcoming to keep costs in line. One of the most versatile basic machines for automatic assembly is the C-frame hydraulic press, wherein stroke, force of the ram or punch, and speed of the operation may be varied for each application. Hydraulic, air, or mechanically powered accessories are available for hundreds of variations. The operation of the press controls are simple and easy to regulate for different requirements.

Typical Assembly Problem

Let's look at an assembly problem, *Fig.* 1, consisting of a small sheave and bracket assembly. The sheave must turn, yet the assembly must be tight enough to avoid end play. Five parts make up the assembly. Two methods are possible: we can preassemble the five parts and then secure them by crimping the rivet on a hydraulic press, or the parts can be fed, one-at-a-time, into successive holding fixtures and then crimped. If the first method is used, production quantity and quality are dependent upon the speed and ability of the worker: in the second, the machine will be responsible for production rates and output will be consistent automatically.

Another factor is involved: the parts must be joined with the same identical crimping force or the tightness of the assembly will vary. If automatic hydraulic power is used, the same identical crimping force can be expected for each assembly. If manual force were to be used, the element of skill and training would be involved. A certain percentage of scrap could also be expected. The choice in this case will be the automatic method with one unskilled worker to attend the press and feed one part.

Automatic Assembly Method

Using the C-frame hydraulic press as the basic power and control unit, we add a hydraulic index table. The table is driven by a hydraulic motor and the interlock of the hydraulic drive is controlled through the valving of the hydraulic press.

Fig. 1—Expanded and assembled views of typical assembly problem

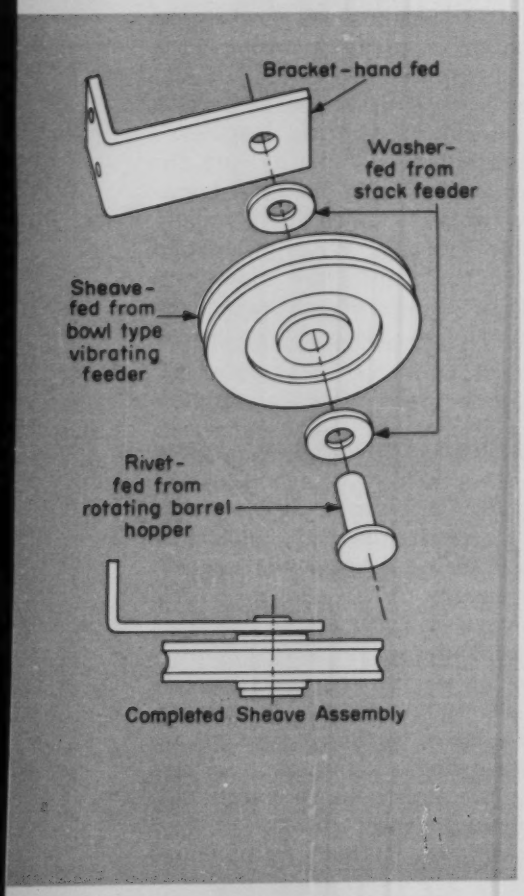
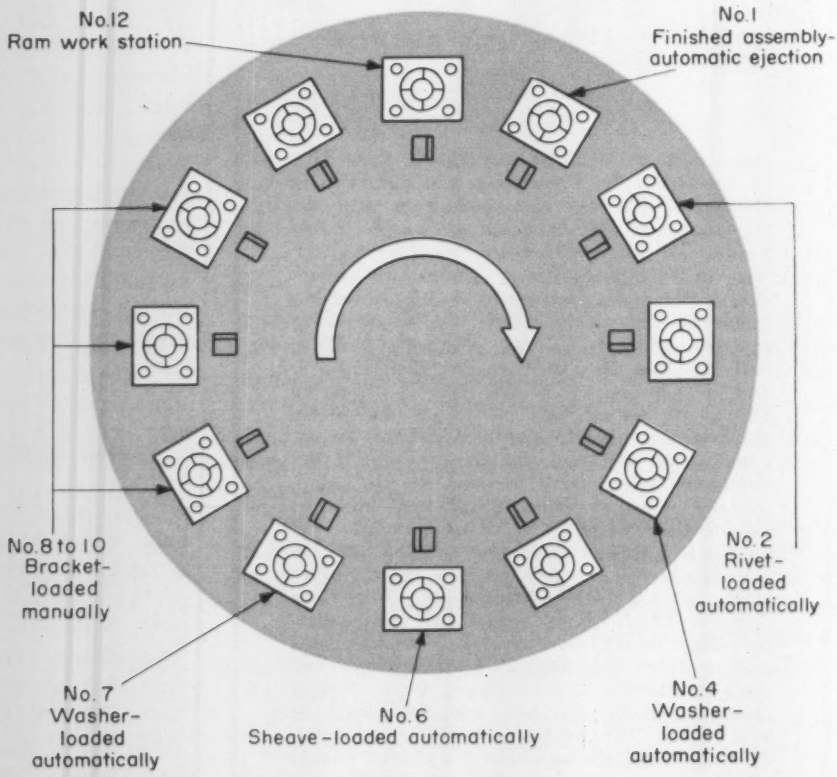

Bracket - hand fed
Washer - fed from stack feeder
Sheave - fed from bowl type vibrating feeder
Rivet - fed from rotating barrel hopper
Completed Sheave Assembly

Fig. 2—Twelve station index table tooled with one manual and six automatic operations


No.12 Ram work station
No.1 Finished assembly - automatic ejection
No.8 to 10 Bracket - loaded manually
No.2 Rivet - loaded automatically
No.7 Washer - loaded automatically
No.6 Sheave - loaded automatically
No.4 Washer - loaded automatically

Tables are available that provide a positive positioning of the table dial to tolerances of plus or minus 0.001-inch, which means that each index of the table accurately positions work beneath the ram of the press. This is accomplished by a positive locking mechanism that slides into position at the conclusion of each indexing motion.

This provides a basic machine for supplying hydraulic force to the assembly and an index table to transport parts to the work stations. This means that the parts may be located on the table while the actual work stroke of the ram is taking place. Time is saved because there is no waiting period between the strokes.

The next step is to design dies or fixtures that will accommodate the various parts of the assembly. Sometimes these fixtures are merely work carriers or nests that hold the parts in position for the pressure application at the ram station. In other cases, complete dies are installed at each station of the table so that each nest is a complete working die for the operation performed. Tables are available for six or twelve-station indexing and their choice is dictated by the size of the job and the number of parts to be assembled. We will use a twelve station table for this job, *Fig.* 2.

We now have the alternative of placing operators to position the parts of the assembly in each nest as it indexes past work stations or installing feeding devices for complete automation. At the 2 o'clock station, *Fig.* 3, we install a barrel type feeding hopper for the loading of the hollow-end rivet. The hopper, which is a standard commercial item modified only to handle various shapes of parts, is slowly rotated by an electric motor. As parts are picked up in a slot of the slide, we are assured that the head of the rivet is down. A trigger mechanism, tripped by cams spaced around the table dial, deposits one rivet in the nest each time the cam is contacted. As the table indexes to the next station the rivet is ready to receive the washer.

At the 4 o'clock station, *Fig.* 4, stack feed magazine is located to place a washer over the rivet. This magazine is a simple tube arrangement with a tripping mechanism to accommodate the washers. The same cams that are used to trip the hopper feed are also used for the magazine and a washer is placed in position. An identical stack feed is also placed at the 7 o'clock station for feeding the second washer.

At the 6 o'clock station, *Fig.* 5, a bowl type vibratory hopper and chute is located to feed the small sheave into the nest. This also is a standard commercial item which can be purchased from several specialists in this field.

As the parts progress past the various feeding devices they reach the final station, *Fig.* 6, where a worker places the mounting bracket on the rivet and the entire assembly progresses to the work station beneath the ram. Here a crimping tool mounted on the press ram crimps the rivet at preset pressure to hold the assembly together.

After the assembly is completed it is automatic-

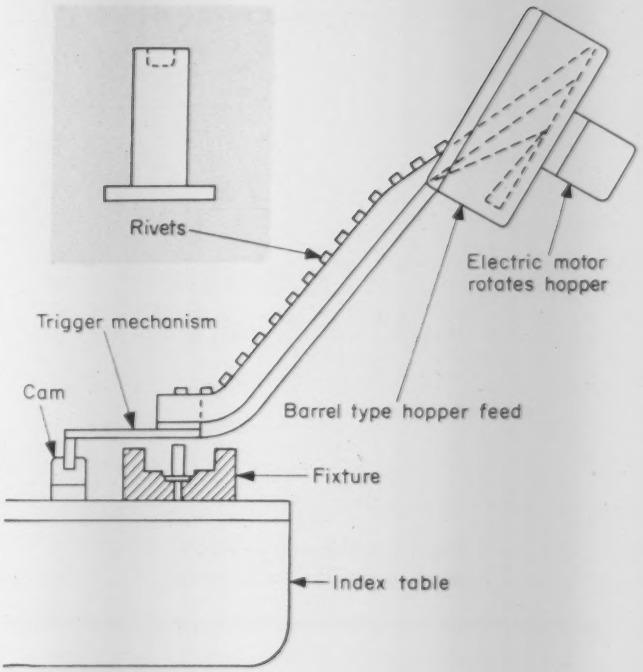


Fig. 3—Rivet loading at 2 o'clock station

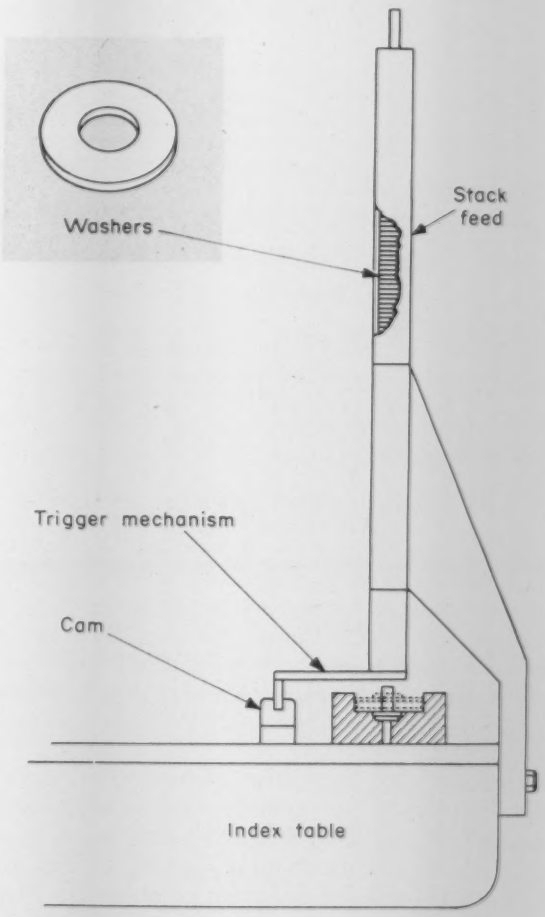


Fig. 4—Magazine washer loader at 4 o'clock and 7 o'clock stations

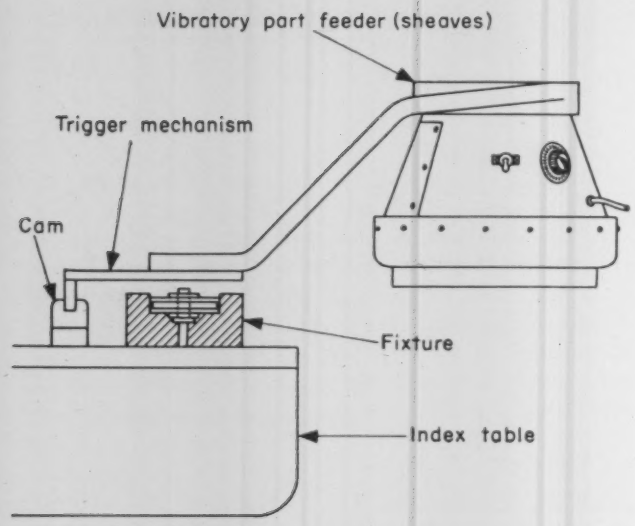


Fig. 5 — Vibratory sheave feeding at 6 o'clock station

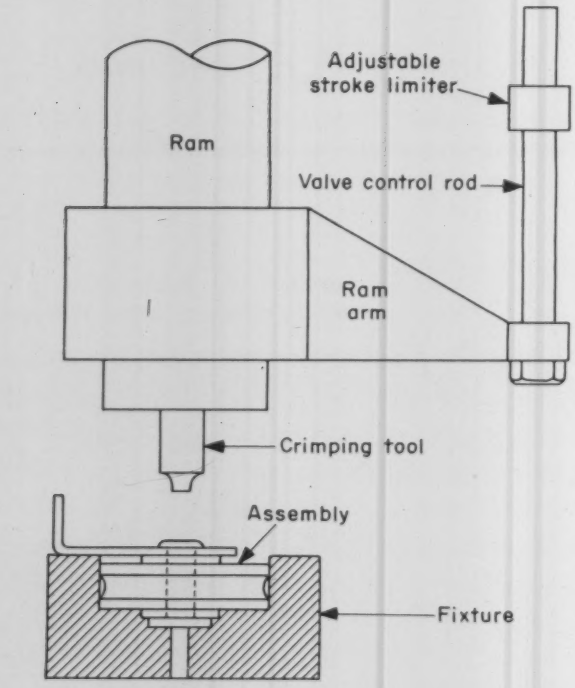


Fig. 6—Rivet crimping at 12 o'clock station

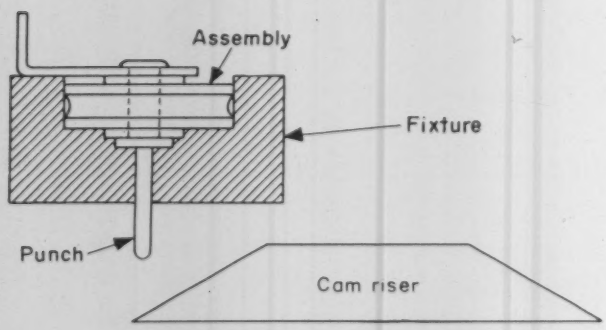


Fig. 7—Ejection of completed assembly at 1 o'clock station

ally ejected at the station immediately following the ram station, *Fig.* 7. A cam is located beneath the dial of the table that actuates a punch in the fixtures, lifting the finished part into a position to be either blown off the fixture by a blast of air pressure, brushed off by an arm or lifted off by mechanical fingers. Air pressure is popular because of its availability. Usually, provision is made so that as the ram descends it contacts an air valve that opens the air line and directs a blast of air on the assembly. Chutes deliver the completed assembly to tote boxes or conveyors.

In setting up this job, the ram stroke is adjusted so that the crimping tool just clears the rotating fixtures. The shortest possible stroke is used to conserve cycle time. Jobs of this type normally produce about 30 assemblies per minute or 1800 per hour.

▶ Automatic Quality Control

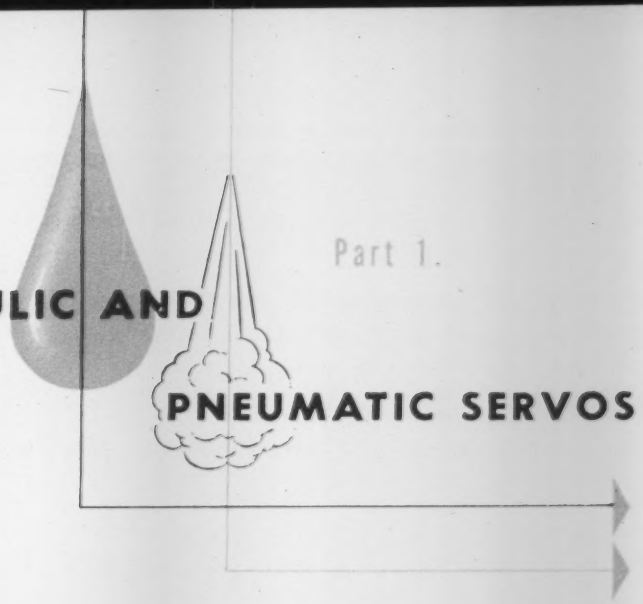
Tonnage of the press is adjusted at the relief valve to provide the pressure needed to crimp the rivet. Too much pressure would clamp the parts so that the sheave would not turn: too little force would result in a loose assembly. In this type of work, hydraulics with their exact pressure stroke for every assembly provide a uniformity that cannot be equalled. The ram reverses at the pressure preset at the relief valve. It cannot exert more than this pressure. Every assembly is automatically controlled for quality of work. Inspection can often be eliminated.

Speed of the operation may be dictated by the speed at which the index table rotates. A flow control valve with simple knurled knob adjustment provides a quick and easy means of changing speed. Once established, production can be controlled for consistent results with the human errors almost completely eliminated. Any worker can keep the hoppers and stack feeds filled, and load the bracket in the fixture. If need be, even the bracket can be automatically loaded.

Special machines such as this are made up almost entirely of standard components available on the market. Any number of other special variations can be worked out using the basic machine as the standard power element.

▶ Cost Considerations

A basic automatic hydraulic press of 5-ton capacity, tooled as illustrated, would cost approximately $10,000. When the job is completed the basic press and index table may be retooled for similar applications for approximately $4,000. Two special machines are therefore available for two separate production needs for about $14,000. The small manufacturer may apply the principles of automation to almost any job. It is equally practical for the large manufacturer and costs are often amortized in less than six months operation.



Part 1.

HYDRAULIC AND PNEUMATIC SERVOS

GENERAL SERVO THEORY

This introduction to hydraulic and pneumatic servos by a leading British authority on the subject is the first of an exclusive series to be presented to the readers of AUTOMATION.

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Engineering Superintendent (Hydraulics)
Sperry Gyroscope Co., Ltd.
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SERVO TECHNOLOGY has made immense strides during the last twenty years, and since World War II a number of excellent textbooks have been published.[1] These deal with the basic theory of the subject, and in some cases also with the detailed technology of electrical servo apparatus, the information—if any—which they give on nonelectrical servos being of an elementary kind. On the other hand, it is well known that for many purposes pneumatic and hydraulic servos have important advantages. Fluid-operated servos require a certain amount of specialized study; the purpose of this series is to provide this specialized knowledge, much of which at present is scattered in articles, papers, and research reports, or altogether unpublished.

[1] References are tabulated at end of article.

The Closed-Loop Concept

In many processes it is essential to achieve accurate control of the value of some physical variable. In some cases the desired value of the variable is fixed at least for a considerable period of time, e.g., the temperature of a domestic oven, the speed of a steam turbine, or the voltage of an electric generator; in other cases the variable under control must follow another variable which changes continuously with time, as for instance the angular displacement of the rudder of a ship, which must follow the movement of the helm.

In the case of the steam turbine for instance, one might endeavor to obtain a fixed speed by giving a fixed setting to a valve controlling the steam supply; this would be called "open-loop" control, and it is obvious that the value of the controlled vari-

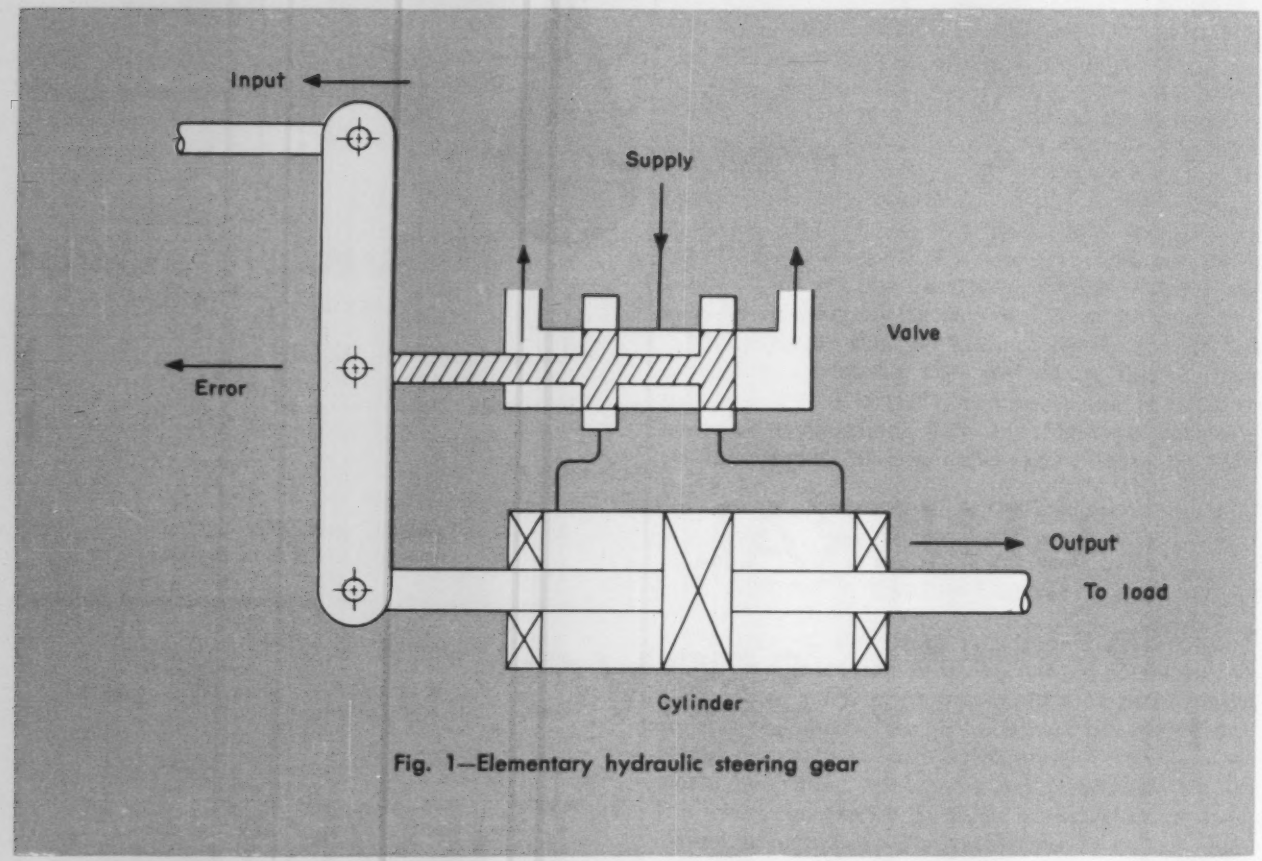

Fig. 1—Elementary hydraulic steering gear

able—the speed of the turbine—would be seriously affected by the pressure of the steam supply and by the load on the turbine output shaft. At best, the speed for any given setting of the valve would depend on the valve characteristics. Sensitivity to power supply, load, characteristics of the apparatus, and perhaps other factors as well, are typical of all open-loop control systems.

These shortcomings can be avoided in the following fashion: Some apparatus is provided which automatically and continuously measures the instantaneous value of the variable under control, and compares it with the desired value. According to the difference between these two, the apparatus acts on the controlling means (e.g., the valve in the case of the turbine) in such a way as to tend to decrease that difference, which will therefore eventually reduce to zero, or at least to a very small figure. Accurate control is thus obtained irrespective of supply pressure, load, or characteristics of the apparatus used. In order to be able to act on the controlling means, the measuring and comparing apparatus must exert some power, which must be accurately controlled according to the requirements of the moment; this function is fulfilled by some power amplifying device.

In the case of the steam turbine, or for that matter any other prime mover, the practical realization of the above scheme is familiar to all, viz., a centrifugal governor. The centrifugal force on the rotating masses measures the speed of the turbine.

The spring setting corresponds to the desired speed, and the movement of the sleeve corresponds to the difference between desired and actual values of the variable in question. This movement is applied to the controlling steam valve, with the result that eventually the actual and desired speed agree within quite close limits. The power necessary to actuate the valve may be drawn directly from the rotating masses, i.e., eventually from the turbine itself. Quite often, however, the governor sleeve merely actuates a hydraulic valve which in turn operates a cylinder which actuates the steam valve, the hydraulic system then providing the necessary power amplification.

Such a system constitutes a typical "closed-loop" control system, but before being more specific as to the meaning of this expression it is useful to consider another instance, say a hydraulic steering gear, as shown in *Fig.* 1. The rudder or wheels which constitute the "load", movement of which forms the "output" are moved by a "motor"—in this instance a hydraulic cylinder—which is itself actuated from the output of a valve that for servo purposes can be described as a "power amplifier". The input linkage conveys the "input" signal—the movement of the steering wheel—to a differential lever, the other end of which is connected to an output or "feedback" linkage connected to the load. The movement of the central point of the lever

then measures the difference between the movements of the input and feedback linkages, and this difference is communicated to the valve.

In general terms, the desired and actual values of the variable at stake are termed "input" and "output" respectively, and are denoted by the symbols θ_i and θ_o. The difference $\theta_i - \theta_o$ is termed "error" and denoted by the symbol e. The process of comparison of input and output is termed "feedback". It is usually assumed that this process consists in subtracting the output from the input to give the error, this subtraction being carried out in the "differential" which may be an easily identifiable component as in *Fig.* 2, or may have a purely virtual existence, as in the centrifugal governor. The error signal from the differential is applied to a power amplifier which in turn feeds some form of motor. The latter may directly move the load, as in the steering gear, or it may actuate a controlling means which affects the process under control.

Closed-loop control processes can be represented by a scheme of dependence, or "block diagram", such as those shown in *Fig.* 2. These represent the simplest types of servo systems. Note that in the case of the steering gear the measuring process, vested in the instrument *I* in *Fig.* 2, purely consists in transmission by a mechanical linkage; in such cases the symbol *I* may be omitted from the diagram.

A distinctiion is usually made between systems such as those typified by the steering gear, in which the input varies continuously with time, and systems such as governors, voltage regulators, thermostatic controls, etc., in which the input is normally fixed. The former are called "servomechanisms", although some authors would restrict the term to those systems in which the variable at stake is a mechanical displacement. The latter are called "regulators"; sometimes the term "regulator" is restricted to quick-acting devices such as speed governors and voltage controllers

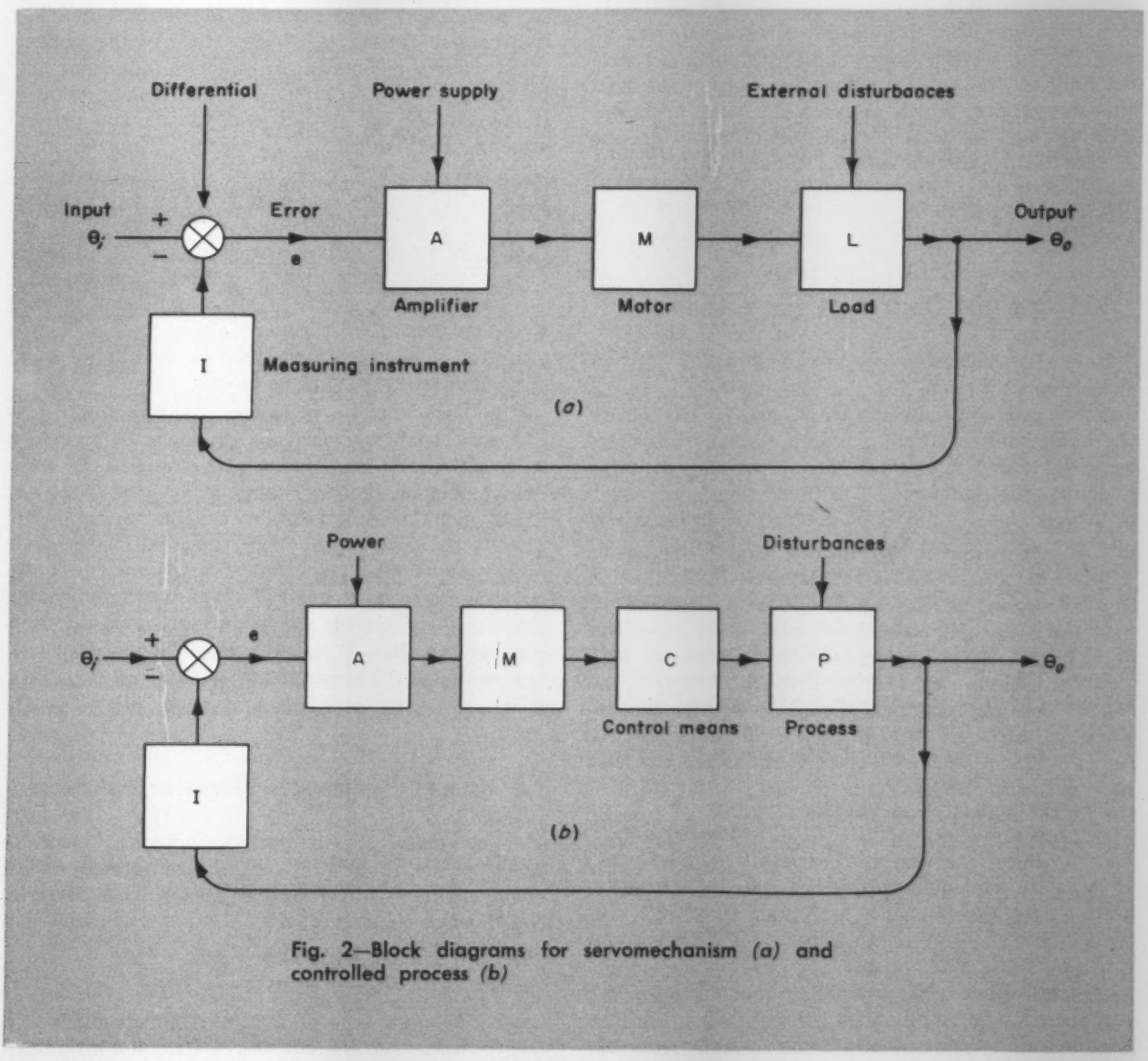

Fig. 2—Block diagrams for servomechanism *(a)* and controlled process *(b)*

while slow-acting devices, which are used chiefly in the chemical industry and are typified by temperature control gear, are described as "process controllers". The terms "closed-loop system", "servo system", or just "servo" are applicable to all the above systems.

The term "load is conventionally taken as applying to such components of the actual load as may be expressed as functions of the output or its derivatives, e.g., inertia, friction, or thermal capacity in the case of chemical processes. Other components, which may be given as functions of time (e.g., wind loads on a gun) are referred to as "external disturbances", see *Fig.* 2.

The arrows in *Fig.* 2 carry the implication that each component affects the next component in the chain, but not vice versa, i.e., the components are deemed to be irreversible. In other words, it is assumed that the output of any component can be calculated from its input only—a very desirable simplification. That this is not always true can be seen in *Fig.* 1; the flow out of the valve depends not only on the valve opening but also on the load on the cylinder, which governs the back pressure. It is however usually possible to find small groups of succeeding components to which the irreversibility condition applies as a group.

▶ Scope and Objects of Servo Theory

It has been established in recent years that all closed-loop systems, from a chemical plant to an automatic pilot on an aeroplane, can be treated by the same mathematical methods. There has thus been developed a general theory of such systems which is quite independent of the kind of component of which the system may consist, which may be electric, mechanical, hydraulic, thermal, etc., or, which is often the case, a mixture of two or more of these. This is possible because the components concerned may have their characteristics expressed by similar mathematical relationships. In this general theory, the components are regarded as sufficiently defined by such mathematical characteristics, and the overall characteristics of the system may then be calculated accordingly.

If it were possible to devise a perfect servo, in which the output was exactly equal to the input at all times, there would be little to theorize about, and the servo engineer's life would be an easy one. It is easily shown, however, that such a system is not physically realizable, and that all actual systems must at least exhibit transient errors when the input, the load, or the power supply changes. Moreover practically all servo systems have some tendency to oscillate, this being inherent in the combination of power amplification and feedback, in the presence of inertia or other delaying effects—if the input changes, the output overshoots the new desired value, then returns and overshoots in the opposite direction, and so on. In the absence of suitable precautions the oscillations may become divergent, or in other words the system becomes unstable. Furthermore any attempt to reduce the magnitude of any errors which may arise almost always increases the tendency towards instability, unless special measures are taken to counteract the effect.

The general theory of servo systems is therefore concerned with the magnitude of errors, with means of minimizing them, with conditions for adequate stability and the means of achieving it.

Knowledge of the behavior of the servo system as a whole must be built up from information as to the behavior of the components which go to make it up. Each of these components—as indeed the complete system is characterized by the relation between its output and its input, the input of any component being the output of the preceding one in the loop. Incidentally, all inputs and outputs are collectively referred to as "signals", and may be mechanical displacements, electrical potentials, hydrostatic pressures, flows, etc. If the characteristics of a component are known, its output may be calculated if the input is given as a function of time—usually the output depends on the present and all past values of the input. Thus an input $x_1 = x_1(t)$, where $x_1(t)$ is some given function of time, will produce an output $y_1 = y_1(t)$, where $y_1(t)$ can be calculated for any value of t, say $t = t_o$, if $x_1(t)$ is given for $-\infty < t \leqq t_o$. Some different input $x_2(t)$ will in general produce some different output $y_2(t)$. If the component is such that the principle of superposition applies, i.e., if an input $x_1 + x_2$ will produce an output $y_1 + y_2$, the component is said to be *linear*.

The basic theory of servo systems applies to systems consisting entirely of linear components. In practice all components are nonlinear to some extent, and many appreciably so, but the theory of linear systems still remains the best path of approach to servo technology, and the basis upon which any more advanced treatment must be built. In accordance with general practice, therefore, we shall assume linear characteristics unless otherwise stated, but at a later stage some effects of nonlinearity will be discussed.

▶ Linear Components, Transfer Functions

It is easily proved that a component will be linear if its input and output are related by an ordinary linear differential equation with constant coefficients, such as

$$a\frac{dx}{dt} + bx = c\frac{dy}{dt} + dy$$

where a, b, c, d are constants. Indeed for present

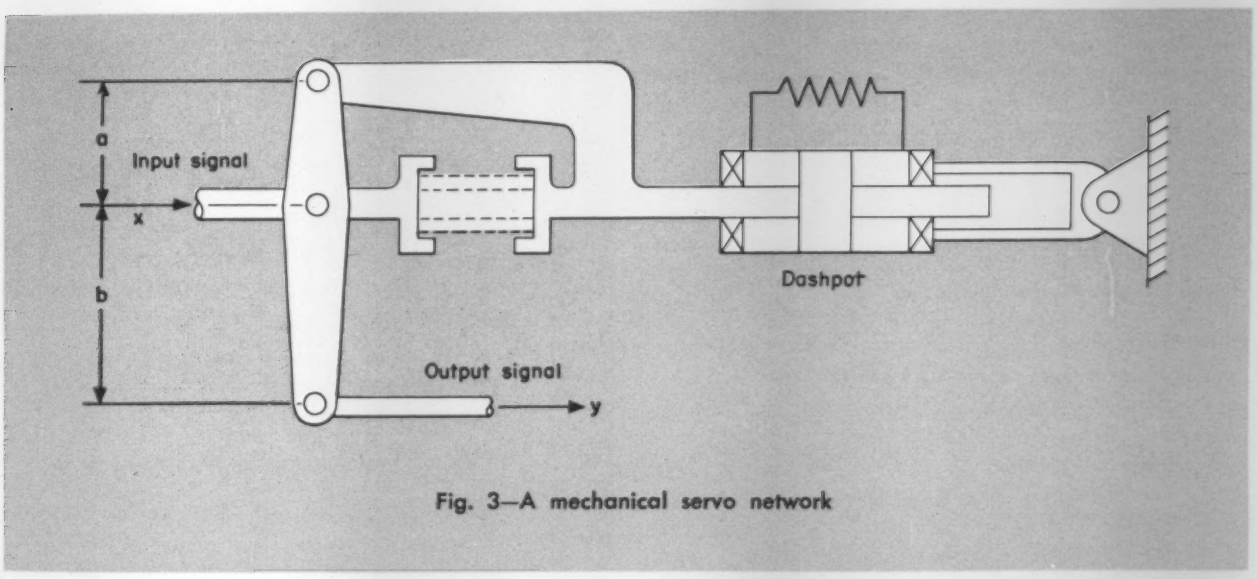

Fig. 3—A mechanical servo network

purposes we may take it that all linear components with which we shall be concerned are such that their input and output are related by an equation of this type (ordinary linear differential equation with constant coefficients).

The differential equation describing the behavior of any component is most often easy to derive from first principles. Take for instance the valve in *Fig.* 1, and let x be the valve travel and q the flow out of the valve. Under certain conditions it may be assumed that the flow is proportional to the valve opening, or say $q = kx$.

A relation of this type is said to define an "ideal amplifier" of "gain" k. Again take the cylinder in *Fig.* 1; let q be the flow into it, y its travel, and A its cross-section area. Then

$$\frac{dy}{dt} = \frac{q}{A}, \text{ or } y = \frac{1}{A}\int q\,dt$$

Such an equation is said to define an "integrator", or "integrating stage", with a "gain factor" $1/A$, the output being the time integral of input.

Consider now the mechanism shown in *Fig.* 3. Assume that the dashpot develops a force proportional to its rate of closure, i.e., the force F is given by

$$F = D\left[\left(\frac{a+b}{b}\,\frac{dx}{dt}\right) - \left(\frac{a}{b}\,\frac{dy}{dt}\right)\right]$$

where D is the damping constant of the dashpot. The closure of the spring is given by

$$z = \frac{a}{b}(x - y)$$

and if the spring rate is R we have $z = F/R$. Combining these equations, we get

$$x + \left[\frac{D}{R}\,\frac{(a+b)}{a}\,\frac{dx}{dt}\right] = y + \left(\frac{D}{R}\,\frac{dy}{dt}\right)$$

this being the desired differential equation connecting the input and output x and y of the mechanism.

It is convenient to write sx for dx/dt, s^2x for d^2x/dt^2, etc. The equation can then be written

$$x + \left[\frac{D}{R}\,\frac{(a+b)}{a}\,sx\right] = y + \left(\frac{D}{R}\,sy\right)$$

or, formally

$$\frac{y}{x} = \frac{1 + t_1 s}{1 + t_2 s} \text{ with } t_1 = \frac{D}{R}\,\frac{(a+b)}{a}$$

and $t_2 = D/R$.

The foregoing expression is not a true ratio of output to input, but merely a shorthand way of writing a differential equation (from the standpoint of the operational calculus the expression is a true ratio of transforms, but this need not concern us here). Such formal ratios of output to input for a linear component are called "transfer functions". Thus, the transfer function of the valve analyzed above is merely the constant k, while that of the cylinder is $1/As$.

In writing transfer functions it is usual (for reasons which will become obvious) to factor out any coefficient of s^0; typical transfer functions might then be

$$\frac{k}{1 + t_1 s},\ \frac{k}{1 + t_1 s + t_2^2 s^2},\ \frac{k\,(1 + t_1 s)}{1 + t_2 s},\ \text{etc.}$$

constants t_1 and t_2 then always have the dimensions of time and are called the "time constants" of the component in question. The constant k is called

the "gain factor" of the component. For single components, the highest power of s to be found in the transfer function hardly ever exceeds two. For any component or system, if the input and output have the same physical dimensions, the power of s in the denominator is never less than that in the numerator.

In the case of components which are not irreversible, transfer functions can often still be obtained for a group of components in sequence, if that group is irreversible as a whole; the procedure will be seen from typical examples at a later stage.

Basic Equations of a Servo System

Consider now a chain or "cascade" of components, the output of each forming the input to the next. Let $h_1(s)$, $h_2(s)$, $h_3(s)$ . . . be the transfer functions of the components. Let e be the input to the first component and let θ_o be the output of the last. Then it is easily shown by the elementary rules of differentiation that the transfer function of the whole chain is given by

$$\frac{\theta_o}{e} = h_1(s) \cdot h_2(s) \cdot h_3(s) \ldots = KY(s)$$

the factor K being so chosen that the coefficient of s^0 in the numerator, and that of the lowest power of s in the denominator, are both unity. K is then the product of the gain factors of all the components in the chain.

A linear servo is deemed to consist of such a chain of components, plus a feedback path and differential, as in *Fig.* 2. It is assumed that the transfer function of the feedback path, including the instrument I in *Fig.* 2 if any, is unity (this is not always the case, and the basic equations will then need slight modification, which can be easily worked out). The input to the first component is then the error $e = \theta_i - \theta_o$, and the output of the last component is the output θ_o of the complete servo. Thus the basic equation relating the output to the error is

$$\frac{\theta_o}{e} = KY(s) \qquad (1)$$

where $KY(s)$ is the "product" of the transfer functions of the components in the chain. Since $e = \theta_i - \theta_o$, it is easily shown by applying the elementary rules of differentiation that the basic equation relating outut to input is

$$\frac{\theta_o}{\theta_i} = \frac{KY(s)}{1 + KY(s)} \qquad (2)$$

Equations (1) and (2) are called respectively the "loop transfer function" and the "overall transfer function" of the servo. They are differential equations relating output to error and to input respectively.

It has been noted above that there may be components—called integrating stages—which have transfer functions of the type k/s, and there may be more than one such component in the chain.

The converse type or pure differentiating component, with a transfer function of the type ks, never occurs and indeed is not physically realizable. Hence, the loop transfer function will always be of the type

$$KY(s) = \frac{K(1 + t_1 s + t_2 s^2 + \ldots)}{s^r(1 + t_3 s + t_4 s^2 + \ldots)}$$

The exponent r, which may be zero, one, or two, but very rarely if ever higher, is called the "order of integration" (or just "order") of the servo. The order r and the gain factor K are highly important parameters in the performance of the servo, as will be shown presently.

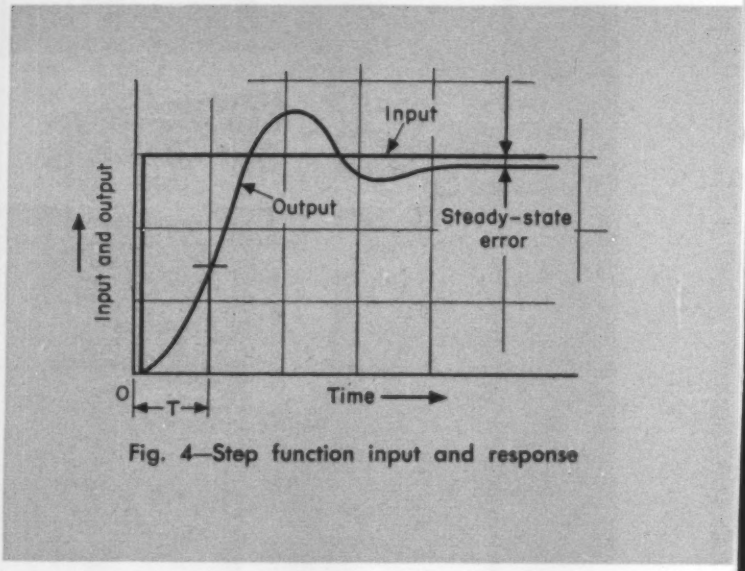

Fig. 4—Step function input and response

Solution of Basic Equations

If the input is given as a function of time, Equation 2 can be solved to obtain the output. In practice, sufficient insight into the perfermance of the servo may be obtained by considering quite arbitrary inputs of very simple types. One of these is the so-called "displacement step function"; the input is zero for $t \leq 0$, and some constant D for $t > 0$. This is shown in *Fig.* 4 together with a typical output corresponding to this input. As time increases indefinitely, the output reaches some steady value which is not always equal to the input, but may differ from it by a small amount, called "steady-state position error", as illustrated in *Fig.* 4. In process control literature, this is usually referred to as "offset" or "load droop".

If the order of integration is unity or higher, putting θ_o = a constant in Equation 1, it is easily seen that $e = 0$ is a solution. Thus if the order of integration is not zero, the steady-state position

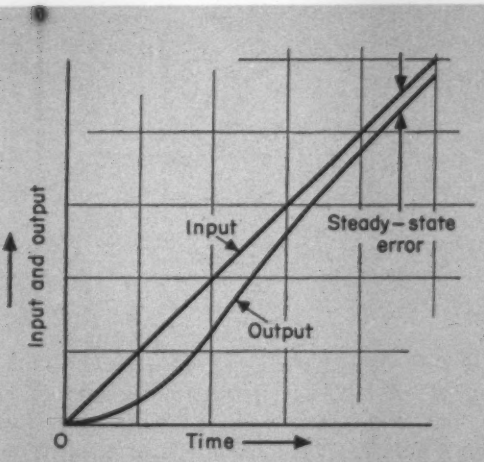

Fig. 5—Velocity step function input and output

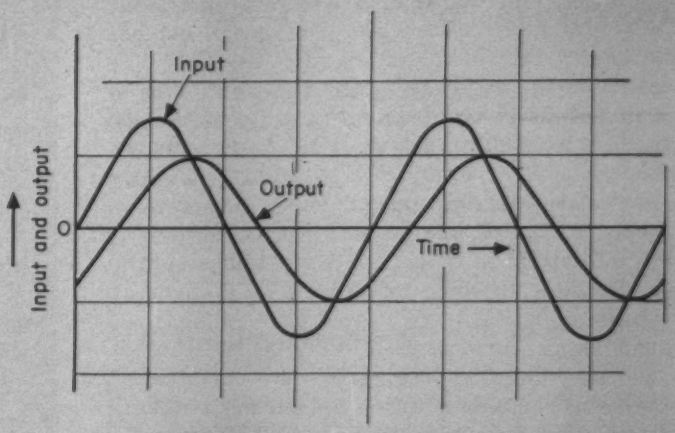

Fig. 6—Harmonic input and output

error is zero. The physical interpretation of this is obvious from *Fig.* 1, which illustrates a first-order servo, if the valve begins to open immediately from the neutral position. If the input is fixed, the output will move as long as the valve is open, i.e., as long as there is any error. Thus, the error will vanish when equilibrium is attained.

If the order of integration is zero, it is seen that Equations 1 or 2 yield a solution (when Θ_o is constant) and ($\Theta_i = D$)

$$\theta_o = \theta_i \left(\frac{K}{1+K} \right) = \frac{DK}{1+K}$$

or

$$e = \frac{\theta_o}{K} \quad \frac{D}{1+K}$$

If the gain factor K is small, the error is large, and the servo fails in its object of achieving accuracy. Hence we may take it that K is large, and write the steady-state position error for a zero order servo as $e \approx D/K$.

The gain factor K is thus an inverse measure of the steady-state position error, and may be referred to (for a zero order servo) as the "position error coefficient".

Another useful input to consider is the so-called "velocity step function", shown in *Fig.* 5; the input is zero for $t < 0$, and equal to Vt for $t > 0$, i.e., the input increases linearly with time from $t = 0$. As time increases indefinitely, the output may or may not reach the same velocity as the input; it can be shown that it fails to do so if the order of integration is zero, and in this case the error increases indefinitely with time. If the order of integration is two or higher, it can be shown (by arguments silimar to those just used) that the output approaches the input indefinitely closely as time increases. If the order of integration is unity, the error will settle down to a fixed value, called "steady-state velocity error"; this is the case shown in *Fig.* 5. Note the steady-state velocity error is an error in position due to constant velocity, not an error in velocity.

Again a similar reasoning to that used above will easily show that for a first-order servo subject to a velocity step input Vt, the steady-state velocity error is given by $e \approx V/K$ provided K is large. Thus for a first-order servo the gain factor K may be referred to as the "velocity-error coefficient", and is an inverse measure of the errors associated with a constant-velocity input.

For a second order servo the steady-state velocity and position errors are, as we have seen, both zero and there is a steady-state acceleration error which is again inversely proportional to the gain factor K. Similar considerations extend to servos of still higher orders, though these are of no practical importance.

Thus, the order of integration of a servo defines at once the most difficult type of input which the system can follow without exhibiting any steady-state error, and the gain factor K is inversely proportional to the magnitude of steady-state errors. Hence increasing that factor improves the performance as far as steady-state errors are concerned. Indeed it could almost be said that the mathematical problem in servo design is that of determining the highest value of K compatible with adequate stability.

▶ Harmonic Response

Much information as to the characteristics of a servo can be obtained by studying its behavior under a harmonic input, i.e., an input that varies sinusoidally with time. If the servo is linear, the output will also be harmonic with the same frequency as the input, but in general differing from

it in amplitude and phase, as shown in *Fig.* 6. The ratio of output to input amplitudes, together with the phase angle, constitute the "harmonic response" of the servo, and this will vary with frequency. At any particular frequency the harmonic response can be represented by a vector, the length of which is equal to the amplitude ratio while its angle to some reference axis is equal to the phase angle.

Consider an input of frequency f, and let $\omega = 2\pi f$ be the "angular frequency" or "pulsatance". In the usual complex notation for harmonic quantities, the input may be written $\Theta_i = C\epsilon^{j\omega t}$, where C is the amplitude, ϵ is the basis of natural logarithms, and $j = \sqrt{-1}$. This can be substituted in Equation 2, enabling the latter to be solved for the input in question. As shown in elementary texts on differential equations, the solution is

$$\theta_o = \frac{KY(j\omega)}{1 + KY(j\omega)} C\epsilon^{j\omega t}$$

THE AUTHOR

RUBEN HADEKEL received his technical education at the City and Guilds College, London University, where he took an honors degree in electrical engineering and a post graduate course in aeronautics. He entered industry to work on aircraft stress problems and early in 1939 joined Messier Aircraft Equipment Ltd. as chief technician. Later as chief designer there, he handled the design of landing gear, hydraulic equipment, and other accessories for some of Britain's wartime and postwar aircraft. After the war he joined B. & P. Swift Ltd., where he was in charge of the Industrial Hydraulics Div. From 1948 until this year, when he became associated with Sperry, he was an independent consultant serving aircraft firms, other industrial undertakings, British government departments, and also lecturing to graduate students. Besides hydraulic equipment and servomechanisms, his work has also involved research and design on pneumatic tires, brakes, aircraft structures, and process control equipment.

or

$$\frac{\theta_o}{\theta_i} = \frac{KY(j\omega)}{1 + KY(j\omega)} \qquad (3)$$

where $Y(j\omega)$ is the transfer function $Y(s)$ with the operator s replaced by $j\omega$.

Similarly, the complex ratio of output to error for the same input is given by

$$\frac{\theta_o}{e} = KY(j\omega) \qquad (4)$$

Now at small values of ω, $Y(j\omega)$ tends to infinity if the servo is of order one or higher, while even if it is of order zero $Y(j\omega)$ is very large for $\omega = 0$. Hence for $\omega = 0$, Θ_o/Θ_i is either exactly or very nearly equal to unity. In all practical servos the power of s in the denominator of Ys is greater than that in the numerator, and hence $Y(j\omega)$ approaches zero as ω approaches infinity. Hence Θ_o/Θ_i approaches unity for small values of ω, and approaches zero for large values of ω. Θ_o/Θ_i is a complex quantity, but its amplitude, denoted by $|\Theta_o/\Theta_i|$, can be easily calculated, and may be plotted against the angular frequency ω, a typical curve being shown in *Fig.* 7.

The "cut-off frequency" ω_o is the frenquency at which $|\Theta_o/\Theta_i|$ decreases sharply towards zero. For a curve such as that of *Fig.* 7, ω_o is not exactly defined, but may be gaged approximately. In practice, ω_o may be defined exactly as the frequency at which the "loop response" $|\Theta_o/e| = |KY(j\omega)|$ is unity; it is easily seen that this is roughly equivalent to the first definition. Input signals of frequency higher than the cut-off value are subject to very strong attenuation, and the cut-off frequency therefore represents the highest frequency with which the servo can deal satisfactorily. Taking a broader view, the magnitude of the cut-off frequency is a measure of the ability of the servo to deal with rapid changes of input. For instance, for a displacement step function input such as that shown in *Fig.* 4, the "transient" or "dynamic" error may be defined as the time T required for the output to reach half its steady-state value and it can be shown that T is roughly inversely proportional to ω_o. Again from the second definition of ω_o it is obvious that it increases with the gain factor K, and the latter is therefore a measure of transient as well as steady-state errors. Transient errors however depend on other factors besides K.

Another important point which emerges from *Fig.* 7 is that $|\Theta_o/\Theta_i|$ may (and indeed usually does) reach a peak, at which it exceeds unity by an appreciable margin, this being a resonance effect which occurs near one of the natural frequencies of the system. The magnitude of this peak is a measure of the degree of damping of the servo. as evidenced by the rate of decay of the oscillations set up by a sudden disturbance, which may be seen for instance in *Fig.* 4. It has been found by experience that if the maximum value of $|\Theta_o/\Theta_i|$ does not exceed about 1.4, the system is adequately damped.

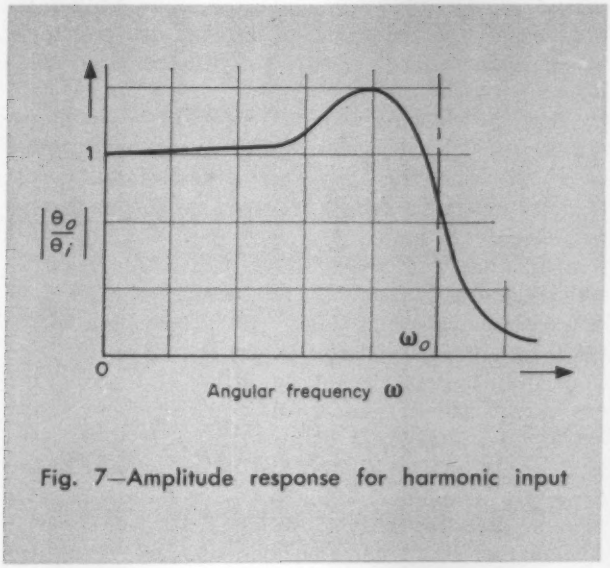

Fig. 7—Amplitude response for harmonic input

The overall amplitude response $|\Theta_o/\Theta_i|$, which is usually denoted by the symbol M, is not very convenient to calculate from Equation 3, particularly since the object of the calculation is most often to find the maximum permissible value of K, i.e., that for which the peak value of M will not exceed 1.4, which is the usual criterion of adequate damping.

The "open loop response" $\Theta_o/e = KY(j\omega)$ is a complex quantity, which can be represented in the usual way on an Argand diagram. This can be done for a series of values of ω ranging from 0 to infinity, and the resulting points can be joined by a curve, which is the locus of the tip of the loop response vector, the other end of which is at the origin. A typical plot is shown in *Fig.* 8; in accordance with usual practice, values of ω are marked on the curve. By definition, the "cut-off frequency" is the frequency corresponding to the point on the curve which intersects the circle of unit radius with center at the origin. From the elementary theory of complex numbers, it is easily shown that on this diagram the locus of constant $M = |\Theta_o/\Theta_i|$ is a circle with center $-M^2/(M^2 - 1)$, 0 and with a radius given by $M/(M^2 - 1)$. Such circles can be drawn on the diagram for various values of M, as shown in *Fig.* 8. The point at which any particular M circle intersects the locus gives the frequency for which M has the value corresponding to that circle, thus enabling a curve such as *Fig.* 7 to be plotted without further calculation. A method which may be even more rapid is to plot the locus of $e/\Theta_o = 1/KY(j\omega)$, for which the loci of constant M are circles which all have their center at the point -1, 0, and radius $1/M$.

In practice still more rapid methods of calculation are usually employed, which are based on logarithmic diagrams. These are described in most textbooks on servo theory, but need not be dealt with here as they are merely computation aids and not necessary to an understanding of the general theory of servo systems.

An important point is brought out by *Fig.* 8. Increasing the gain factor K is equivalent to drawing the locus to a larger scale and this will result (for the locus shown) in a higher peak value of M. Thus increasing K will usually reduce the degree of damping of the system. Indeed, one of the chief purposes in drawing this type of diagram (or logarithmic diagrams) is to determine the maximum value of K for which the peak value of M will not exceed some critical figure, usually 1.4 or thereabouts.

Stability Conditions

The condition that M must not exceed some specified peak value is necessary to ensure adequate damping, but it does not guarantee that the servo will be stable and will not develop divergent oscillations. It can be shown that the necessary and sufficient condition for a servo to be stable in the absolute sense—free from divergent oscillation and nonoscillatory divergence—is that the roots of its "characteristic equation" all have negative real parts. The characteristic equation is the equation obtained by substituting the algebraic variable u for the operator s in the denominator of the right-hand side of Equation 2 and setting the resulting expression equal to zero,

$$1 + KY(u) = 0 \qquad (5)$$

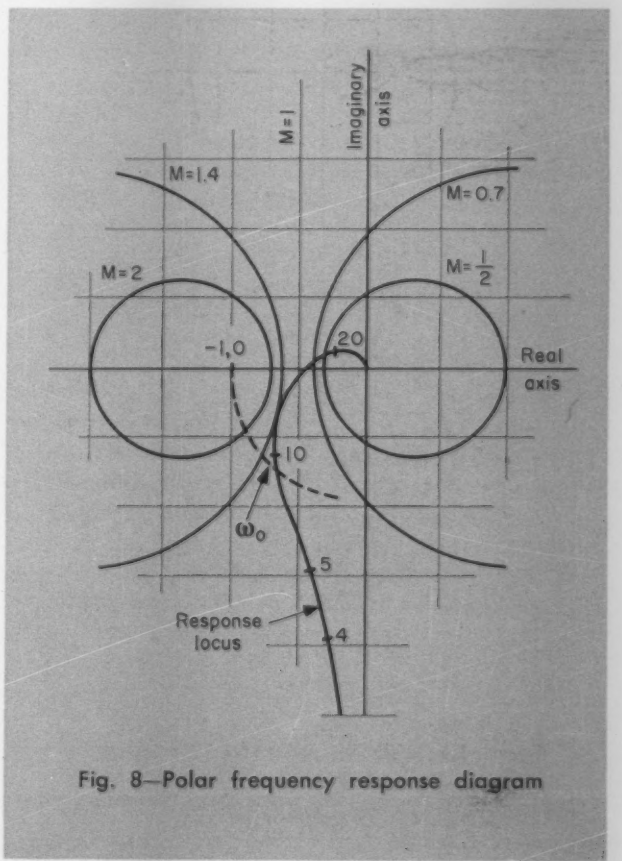

Fig. 8—Polar frequency response diagram

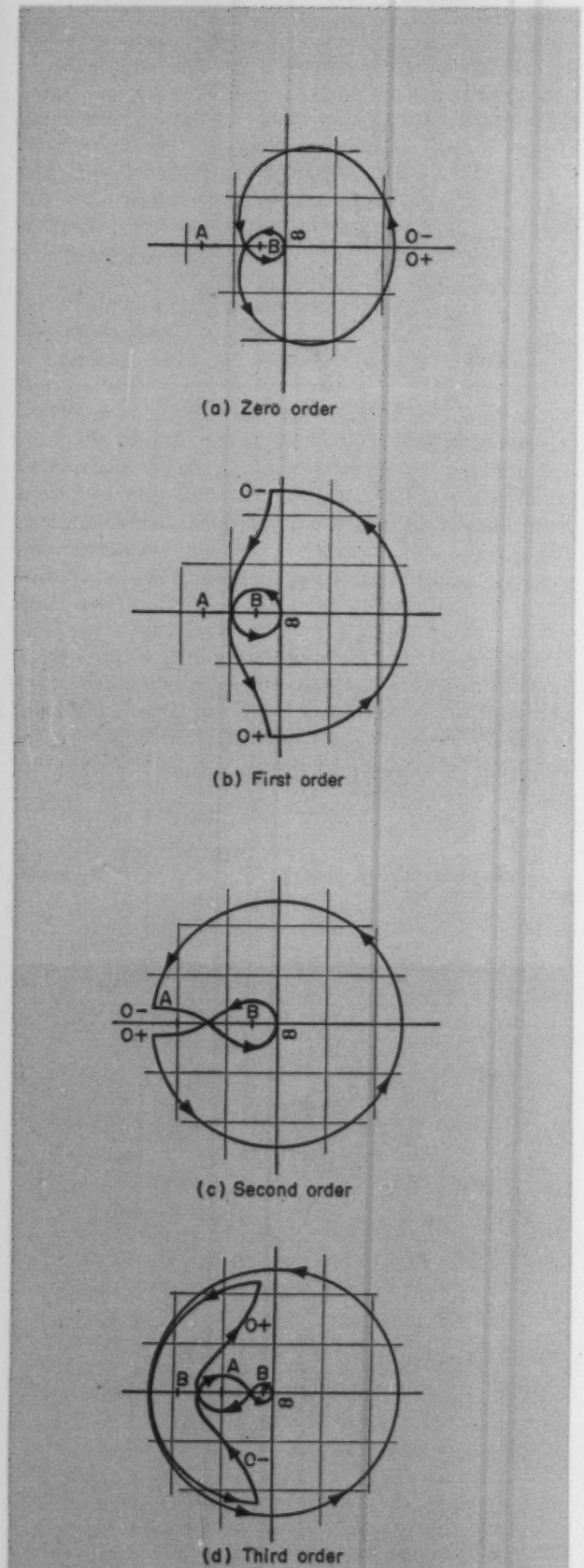

Fig. 9—Nyquist loops for typical servos. Servo is stable if point (−1,0) is at *(A)*; unstable if point (−1,0) is at *(B)*

This is an ordinary algebraic equation in u. Fortunately, as the equation is often of quite high order, it is possible to ascertain the necessary information as to the roots of the equation without solving it. One method of doing this is to apply the Routh-Hurwitz criterion.[3,4] Another method, more frequently used by servo engineers, is the Nyquist criterion, which is based on the harmonic response of the loop.

A Nyquist diagram is simply a plot of the open-loop response vector $KY(j\omega)$, exactly like *Fig.* 8 but with certain additions. First, the plot is extended to negative frequencies, the negative portion being merely the mirror image of the positive portion in the horizontal axis. Frequencies are marked on the locus at intervals. If the servo is of order one or higher, the locus extends to infinity for $\omega = 0$, and the branches corresponding to very small positive and negative values of ω are marked $0+$ and $0-$ respectively. Arrows are added to indicate the positive sense on the locus, which is from $0-$ to ∞ to $0+$. The branches $0+$ and $0-$ are joined by an arc of a circle of large radius, the positive sense on this being counterclockwise from $0+$ to $0-$. This arc of circle embraces 180 degrees for a first-order servo, 360 degrees for a second-order servo, 540 degrees for a third-order servo, etc., and makes the diagram into a closed curve. Typical diagrams for servos of order zero, one, two, and three are shown in *Fig.* 9(*a*), (*b*), (*c*) and (*d*) respectively.

The Nyquist criterion states that the servo is stable if, and only if, the diagram does not encircle the point -1, 0. Thus, if in all the diagrams of *Fig.* 9 the point -1, 0 is at *A*, the servo is stable, whereas if that point is at *B* the servo is unstable. The meaning of "encirclement" is not always obvious in some cases, e.g., *Fig.* 9*d*, and the word may be defined as follows: Imagine a pole projecting from the paper at the point -1, 0, and imagine the locus to be an endless piece of string. If the string can be taken away without lifting over the top of the pole, there is no encirclement, and vice versa.

In this form the Nyquist criterion applies only to the simplest case, although by far the most important, which is that of servos made up of stable components. In some cases some of the components in the servo may be themselves closed loops, and these need not necessarily be stable. Just as a chain of stable components may be made unstable by closing the loop, so a chain of components, one or more of which are unstable, may become stable when the loop is closed. In such cases the Nyquist criterion takes a modified form.[1]

Second part of this series, to cover servo performance, will appear in the November issue.

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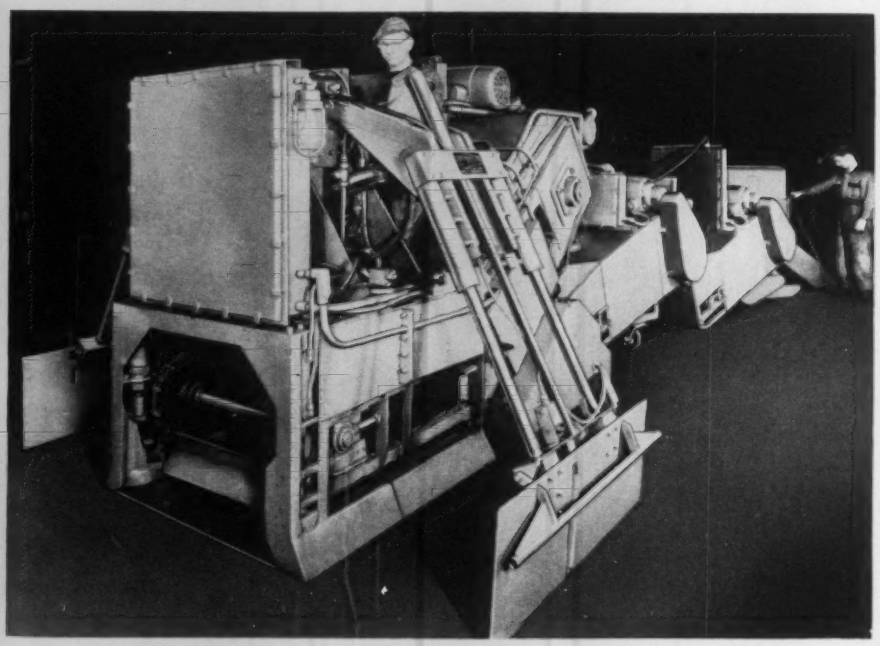

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Cargo handler unloads any free flowing bulk material, such as grain, salt, chemicals, sulphur, cement, from railroad box cars automatically by conveyors. While front end of a flight conveyor eats into cargo, two hydraulically controlled, adjustable side scraper arms stretch to walls of box car and scrape material into the conveyor. Side arms cover full width of car so that when machine has reached the end of a car in one pass, that entire end is empty. Material is conveyed through articulating units of belt conveyors out of box car into hoppers and thence to belts under the railroad which carry it to elevators. Flight conveyor is driven by caterpillar tracks. Two hydraulic cylinders on casters lift front end of machine off the box car floor to back it out. Control of side arms can be automatic or manual. Unloading capacity is 10,000 bu grain per hour. **Cargo Handlers Inc.**, 23501 Hoover Rd., Van Dyke, Mich.

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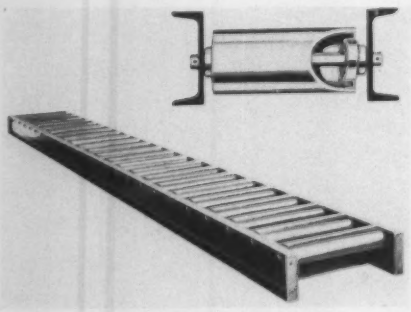

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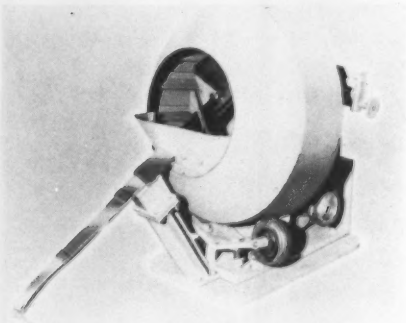

TUMBLE HOPPER

Variety of parts can be fed at high rate of speed to assembly presses, centerless grinders, secondary operation machines, and other production machinery by this tumble hopper. Largest of three available sizes is illustrated and measures 24 in. in diameter. Unit is self contained, mounted on a flat base, constructed of fabricated steel, powered by a ¼-hp, 3-phase motor with built-in variable drive. Pieces handled include washers, nut blanks, nuts, special stampings. **Feedall Machine & Engineering Co.**, 38399 Pelton Rd., Willoughby, Ohio.

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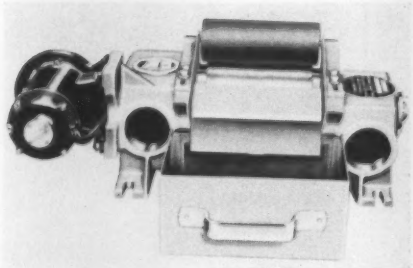

COOLANT SEPARATOR

A magnetic separator for liquid coolants can be installed on machine tool sump to give longer wheel and tool life and better product finishes. Continuously operating separator automatically filters ferrous metallic particles from coolants and cutting oils. Particles are removed by permanent ring magnets enclosed in a revolving cylinder with 360° constant magnetic attraction. Turbulent flow of coolant in channel below cylinder holds metallic particles in suspension until attracted by magnetic field. Nonmagnetic wiper trough collects particles. Cylinder is driven by a 1/70-hp (4.8 rpm) gear head motor, can operate from 110-v control circuit. Separator is available in 10 and 20 gpm capacities for soluble oils, and in 5 and 10 gpm for mineral oils. A 10 gpm model measures 20 x 7⅞ x 6½-in. **Honan-Crane Corp.,** Lebanon, Ind.

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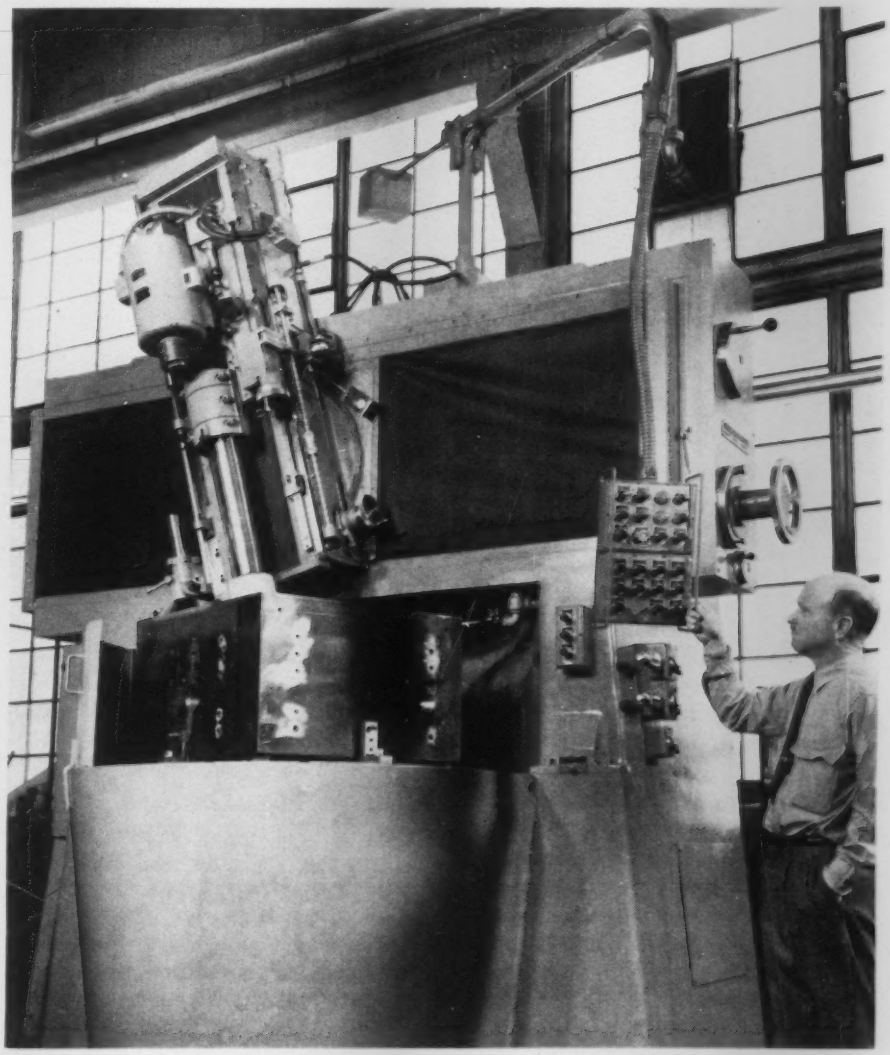

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A vertical universal 42-in. grinder, with a normal maximum swing of 52-in., features a push-button pendant station for all operating controls. In addition to all types of vertical grinding, this hydraulically operated machine will handle surface grinding, with accuracy and concentricity. Head can be set at any angle up to 45°. Both male and female parts can be ground and finished to fit with head set at one angle. Tapered or straight holes can be ground to a depth of 2 ft. Standardly equipped with one head, machine can be modified to use of two or more. Spindle speed rises to 88 or 176 rpm, and grinding stroke is 27½-in. at speeds up to 185 in. per minute. Ten hp wheel spindle motor runs at 3600 rpm and 7½-hp hydraulic system motor at 1200 rpm. Clearance over face plate is 25-in., and over work spindle is 30¾-in. Coolant splash guards have been removed in illustration for clarity. **Springfield Machine Tool Co.,** 631 W. Southern St., Springfield, Ohio.

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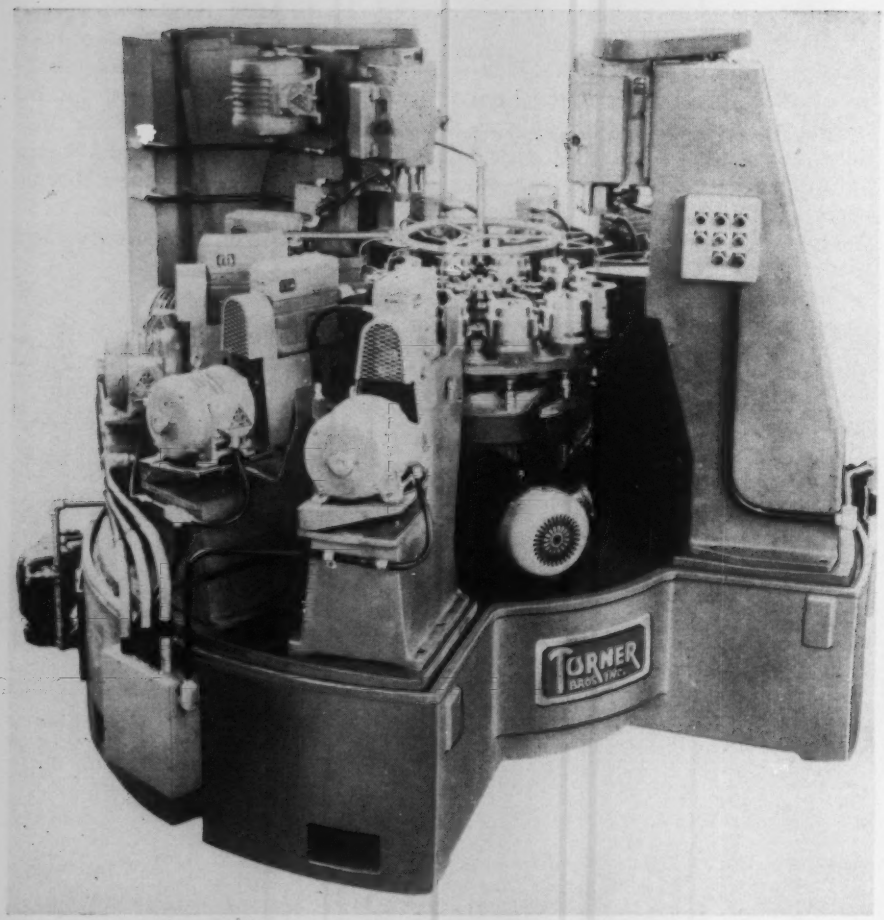

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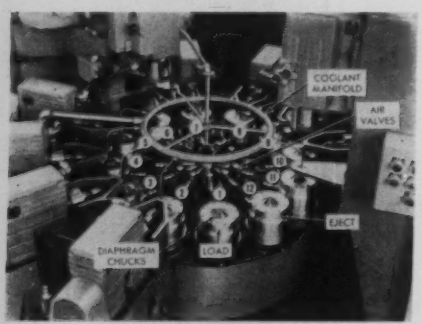

are drilled in the next four stations. A vertically mounted reamer reams a 0.406-in. diam hole and removes burr caused by drilling. Four more stations repeat drilling operation, and a duplicate reaming operation removes burr again. Part is automatically ejected from machine. Only loading is performed manually. All components are standard. **Turner Bros., Inc.**, 2625 Hilton Rd., Ferndale, Mich.

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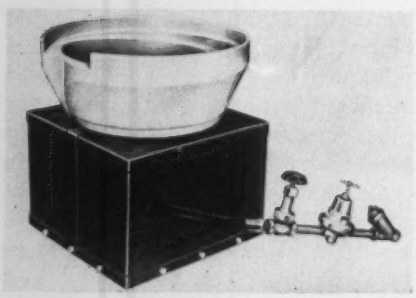

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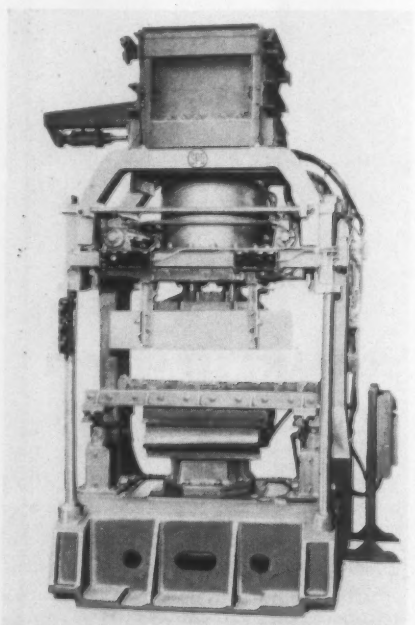

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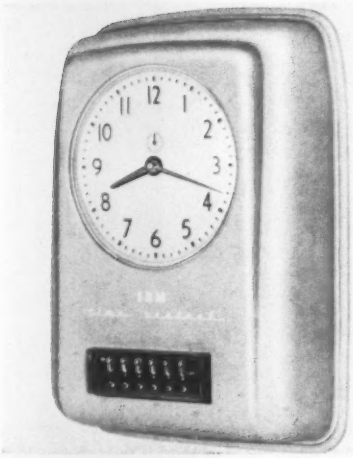

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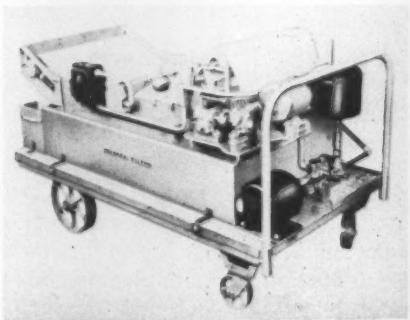

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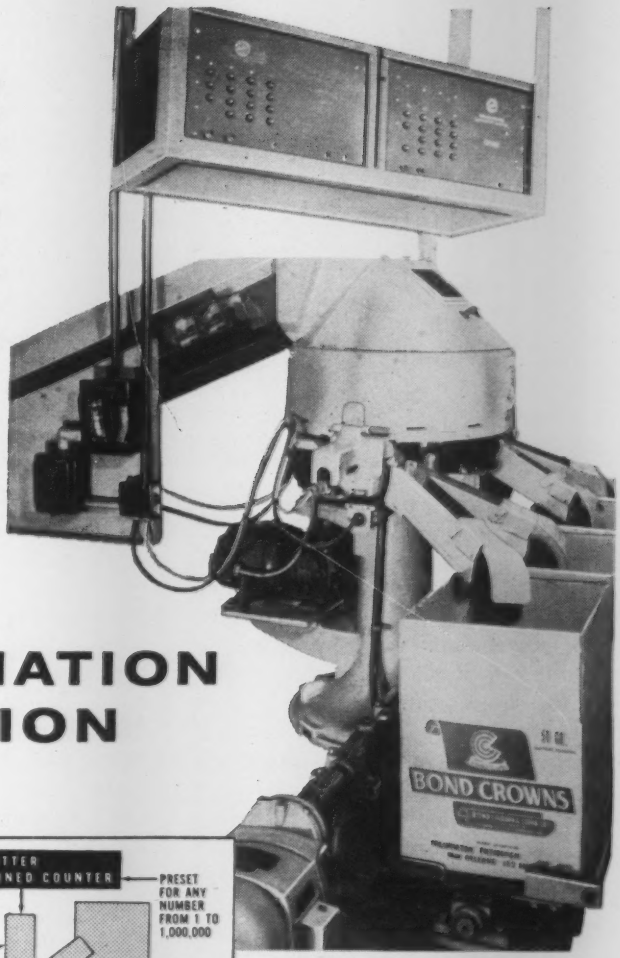
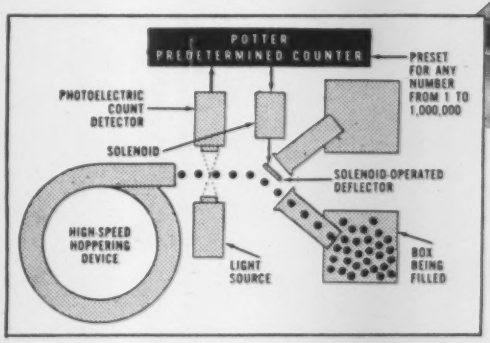


AUTOMATION IN ACTION



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- Eliminates customer complaints due to short counts.
- Eliminates costly overcounts.
- Frees operators for more productive work.
- Packaging becomes automatic and limited in speed only by capabilities of production machinery.
- Completely electronic—no moving parts to wear.

Automation need not be complicated and expensive. Many users have installed Potter systems without interrupting production. Exclusive circuits assure long-lasting trouble-free operation. Also available is a complete line of photoelectric, electromagnetic and impact count detectors.

Send full details of your packaging or control problem today. Our applications engineers will be pleased to submit a detailed proposal. No obligation, of course.

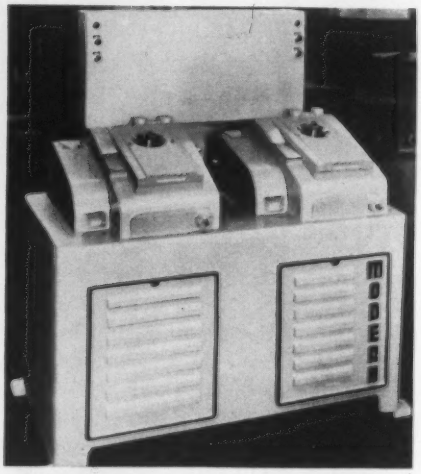
Potter POTTER INSTRUMENT COMPANY, INC.

115 Cutter Mill Road, Great Neck, N. Y.

AUTOMATIC TAPPET GRINDER

Spherical radius on heads of automotive valve tappets are automatically ground with 0.015-in. stock removal by four grinding spindles mounted at right angles to the holding fixtures on a new grinder. Tappets are placed in hopper, travel into a double track loading mechanism which is cammed to load two tappets into the fixture simultaneously. Table containing 160 individual V-type holding fixtures rotates clockwise continually at approximately 140 in. per minute. Tappets cross the face of each of the rotating grinding wheels, the fourth of which has a special wheel to give a fine finish. Each head has automatic infeed to compensate for wheel wear. After the finish grinding the tappets are automatically ejected into a takeoff chute, and fixtures are flushed by coolant before reaching the loading station. Approximately 4000 pieces are turned out per hour with an average surface finish of 10 mu in. **Motch & Merryweather Co.**, Penton Bldg., Cleveland 13, Ohio.

Circle No. **12** *on Reply Card*



GEAR PROCESSOR

Universal gear deburring and chamfering machine has two stations to process spur and helical gears, and straight and involute external splines from ⅝ to 6½-in. pitch diameter. The two stations can be tooled to identical operations, to successive steps on the same gear, or to deburring and chamfering totally different parts. Machine chamfers entire tooth form, two sides and root, in 0.2 second. Placement of part on work spindle moves a cycle indicator arm to starting position. Ensuing operation is automatic until a light signifies cycle's completion. Retooling from one job to another is accomplished easily in ten minutes. Each station contains demountable pilot gear, tool block and form cutter. Precision tooling is developed on master machines at company plant, and is then interchangeable with similar models. All components are accessible for servicing, all controls are reached easily, and cutters can be removed for sharpening. Moving parts are enclosed, and a special safety cover protects operator during loading and unloading. **Modern Industrial Engineering Co.**, 14230 Birwood Ave., Detroit 38, Mich.

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AUTOMATIC CONTROL OF VARIABLE SPEEDS

VARITROL®
RECEIVES 3 TO 15 PSI SIGNAL
OUTPUT SHAFT RESPONDS WITH VARIABLE SPEEDS
See "AUTOMATION IN ACTION" At Booth Number 2012— National Metals Exposition, Chicago, Illinois, Nov. 1 thru 5, 1954
An operating model of automatically controlled processes by U. S. Varidrive with Varitrol control will be displayed.
MOTORS
¼ TO 50 HP
U.S. VARIDRIVE
THE MIRACLE MOTOR
WITH
VARITROL®

Now any process requiring automatic variable speeds can be driven by U. S. Varidrive with Varitrol control. For more than 20 years the Varidrive has been recognized as the most compact and efficient device for obtaining variable speeds, with ratios up to 10:1 and capacity from ¼-50 HP. Varitrol is a new control device which regulates the speed of a Varidrive in response to a signal. The signal is obtained from a standard type of pneumatic instrument sensitive to such variables as:

Temperatures	Liquid Level
Humidity	Weight
Pressure	Tension
Speed	Position

Many firms are increasing productivity with Varitrol control. Quality of product is improved, human effort is reduced. Lower costs result in better salability of your products.

U. S. Engineers are experienced in variable speed problems, and can help you apply Varidrives to your process.

Request new Bulletin on Varidrives with Varitrol automatic control. Indicate if you would like additional literature on Varidrives.

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Box 2058, Los Angeles 54, Calif. or Milford, Conn.

☐ Send also 16-page 4-color Booklet on Varidrives

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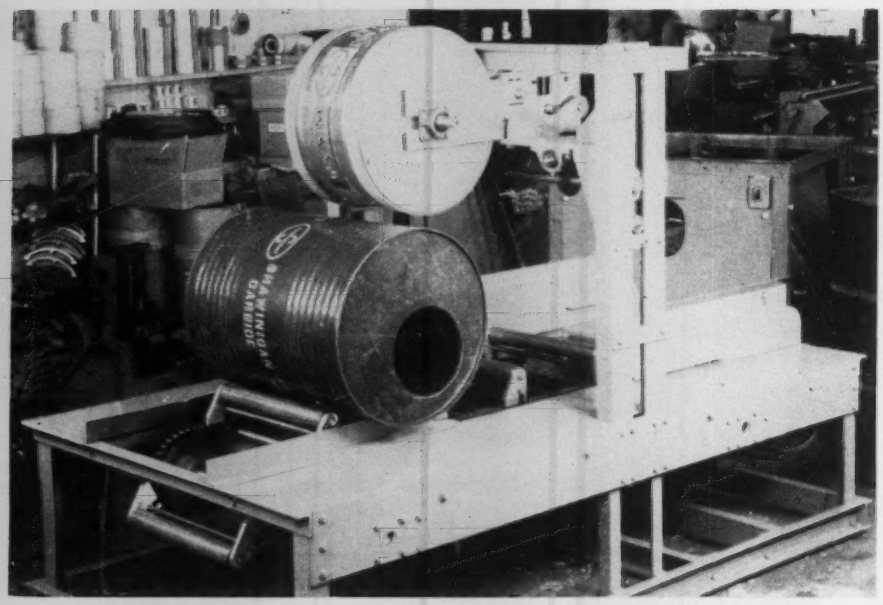

DRUM PRINTER

Fifteen 100 and 250 lb drums per minute can be printed automatically by a new machine which facilitates in-plant printing and eliminates screened system printing. Drums are loaded manually onto a cradle which positions them under the continuously revolving printing wheel. Wheel spins and prints drum which is then automatically ejected. Different diameters of drums are handled by raising and lowering the printing heads. **Industrial Marking Equipment Co.,** 454 Baltic St., Brooklyn 17, N. Y.

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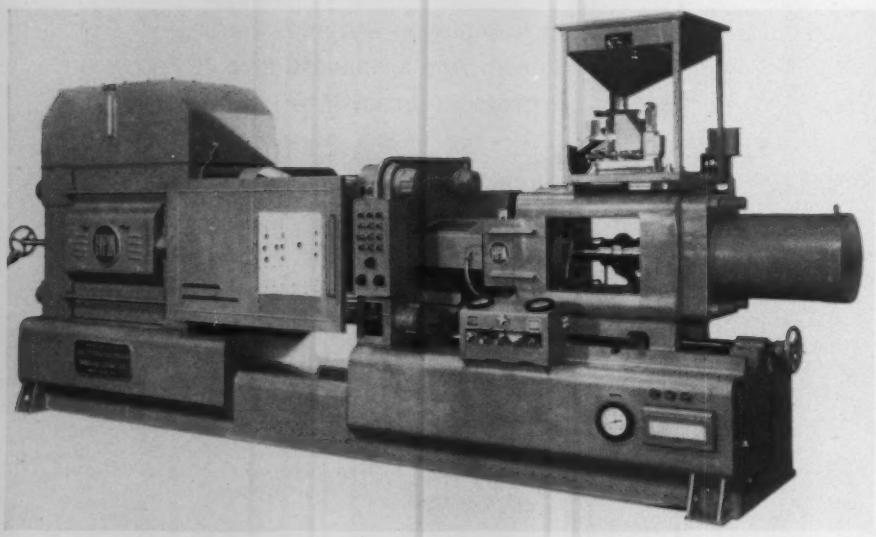


PLASTICS INJECTION MOLDING MACHINE

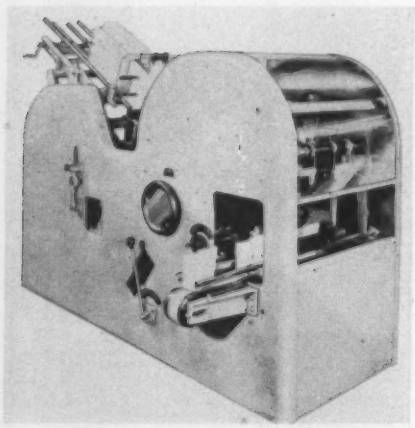
To accommodate the trend toward larger plastic parts used in table model radios, cabinets, toys, refrigerator parts and housewares, a high speed 20 to 28 oz injection machine is now available. Increase from 30 to 50 hp over former large 16 oz machine, and 60 per cent higher injection speeds are reported. Materials are weighed accurately for each molding by an automatic, compensating type weigh feeder. Injection unit is mounted on ways and hydraulically retractable, and has a hydraulically actuated, positive sprue break to be used at operator's discretion. A dual injection pump permits two speed injection or dual pressure injection, can be used as a timed control for automatic reduction of injection pressure after mold cavities have been filled.

High pressure axial piston pump develops maximum clamp pressure in the hydraulic circuit, and double-vane pump operates clamp and injection rams. Mold clamp has fast closing and opening speeds with automatic adjustable slowdowns prior to mold contact, at mold breakaway, and during ejection of molded part. Also, it eliminates time consuming adjustments when mold thicknesses vary. Plasticizing chamber is equipped with three pyrometer controlled heat zones. Platen and die areas are increased to accommodate larger mold areas. An overhead oil tank prevents contamination of oil with dirt, water, or plastic. **Hydraulic Press Mfg. Co.,** Mount Gilead, Ohio.

Circle No. **15** *on Reply Card*

CONTAINER MACHINE

Said to be the fastest equipment built for forming and lining cartons for lard and shortening, this fully automatic machine will process up to 120 cartons per minute. Machine is adjustable on location to handle 1 to 4 lb cartons. Easily accessible carton and liner paper loading stations, and 22-in. high conveyor line add to ease of operation. Cartons and liners are folded while moving up the line to facilitate handling and to produce a better package. Carton lock is positive due to rotary tuckers and stationary carton tongue lifting fingers. **Peters Machinery Co.,** 4700 N. Ravenswood Ave., Chicago 40, Ill.



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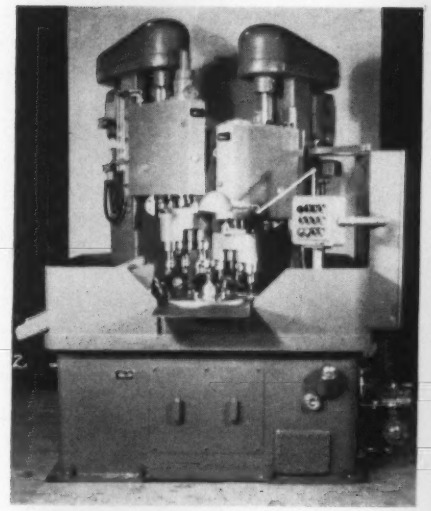
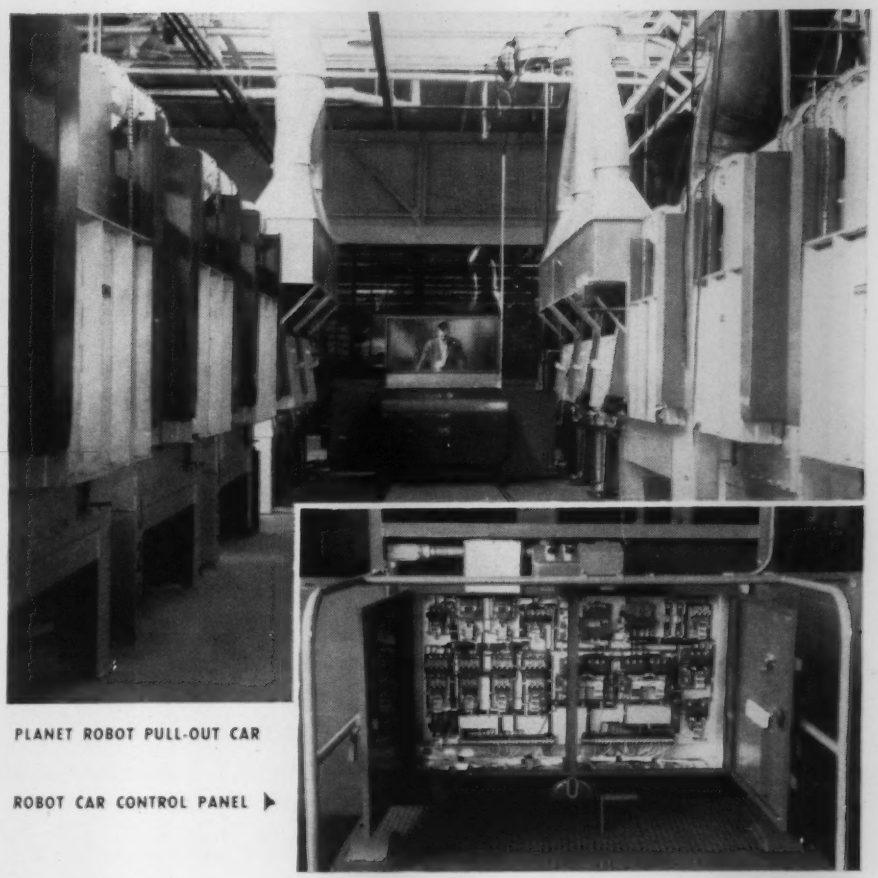


DRILLING AND TAPPING

A single-head, automatic, combination drilling or tapping unit is the basic model for a line of hydraulic machines (two-head model is illustrated). Machine can use head as a single spindle or can be arranged with a multiple head to drill or tap two or more holes at a time. Drilling unit switches to tapping with minor adjustments and installation of lead screw assembly. Long lived lead screw running in an alloy bronze nut with constant pressure lubrication and cooling at high speeds assures lead screw control. Feed control is accurate with quick traverse on downward and return strokes. Spindle has a built-in torque control which automatically reverses and stops spindle at top of stroke. Resetting and eliminating the overload is required before continuing operation.

Twelve tapping speeds range from 236 to 1328 rpm while drilling can be as rapid as 2000 rpm. Hydraul'c clutch provides unlimited number of reversals per minute at twice the forward speed. Heads may be used in vertical or horizontal position with or without an indexing table. However, addition of an indexing table permits mounting of four or more 2-jaw hydraulic self-centering chucks. Addition of flanged quill will adapt multiple spindle heads to tapping or drilling as many holes simultaneously as necessary within machine's capacity. Floor space required is 48 x 80 in. **Kaufman Mfg. Co.,** Manitowoc, Wis.

Circle No. **17** *on Reply Card*



PLANET ROBOT PULL-OUT CAR

ROBOT CAR CONTROL PANEL ▶

to load and unload furnaces...
automatically...

Just Press A Button

This PLANET robot car, specially designed for heat treating operations at a large automobile plant, is completely automatic and entirely self-propelled. It loads and unloads trays of forgings weighing up to 600 lbs. from furnaces at *either side,* permitting a compact, space-saving installation.

Here's automation in action . . .

Trays are withdrawn from a right hand furnace and discharged into furnaces on the left. The entire cycle is handled by pushing one button.

If you have a materials handling problem, it will pay you to "Plan with Planet". Experienced Planet engineers design and install specially engineered systems complete from the preliminary survey and specifications to installation and testing.

Write today . . . for information on applying automation to your operations.

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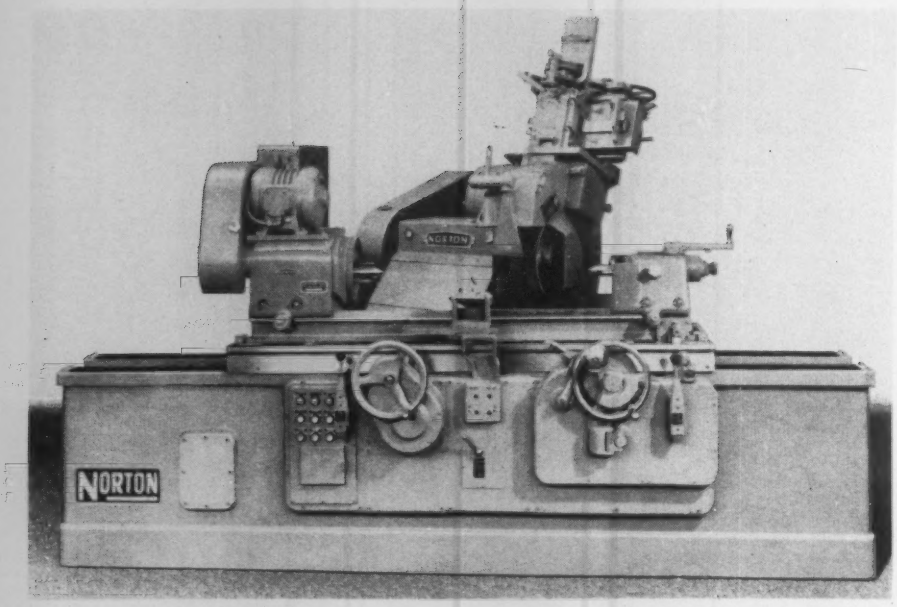
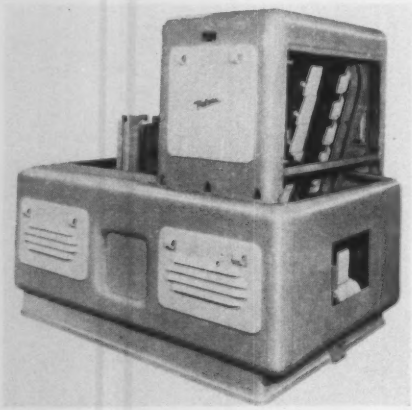


SEMIAUTOMATIC ANGULAR WHEEL SLIDE GRINDER

Angular machine grinds thrust surfaces and adjacent diameters simultaneously in a single, automatically controlled plunge grind, eliminating separate operations and producing a concentric grain pattern in finish of shoulder or thrust surface ground. Accurate faster sizing is due to efficiency of the hydraulically rotated, micrometer-screw feed mechanism. A graduated wheel continually indicates amount of feed as it rotates past a fixed pointer. Both length and rate of automatic feed can be set from normal operating position. "Click-count" index makes settings for work diameter reduction in increments as fine as 0.0001-in. instantly without operator's attention.

Operator must load, touch off the control which starts the grinding cycle, rotation, and coolant flow, and must remove the work upon automatic termination of the grind. A truing device is available which will true wheels automatically to required form by pushbutton and will give uniform control of amount of abrasive removed from wheel. Heavy wheel spindle unit is extremely resistant to grinding pressures, will mount grinding wheels with faces as large as 8-in. For multi-wheel mounting, wider wheelguards can be supplied. Also featured are a ramped outlet in coolant tank for cleanout, outside location of pumps and motors for accessibility, grouped electrical controls, and an auxiliary hand drive mechanism in addition to the hydraulic power table drive. Machine is available in 10 and 14-in. swings, with 36, 48, or 72-in. work lengths in either swing. **Norton Co.**, Worcester 6, Mass.

Circle No. **18** *on Reply Card*



CARTON FORMING

Low cost blanks are converted automatically into shaped glued cartons or trays at speeds of 175 or more per minute by this forming and gluing machine. Unit is adjustable to a wide range of top opening, hinged cartons, drug items, hardware specialties, etc. Carton blanks can range from 6 to 18 in. long, and from 9½ to 22 in. wide. "Perfect package" control is achieved during the gluing cycle where blanks are held firmly by V-lock clamps while they rotate through the complete glue setting cycle, which is substantially longer than on most machines to permit the glue to set firmly. V-lock prevents any slipping, sliding, or shifting, and insures perfectly squared and formed cartons. Operation requires only two cams and a ¾-hp drive motor. Floor area is 5 x 6 ft. **Peters Machinery Co.**, 4700 N. Ravenswood Ave., Chicago 40, Ill.

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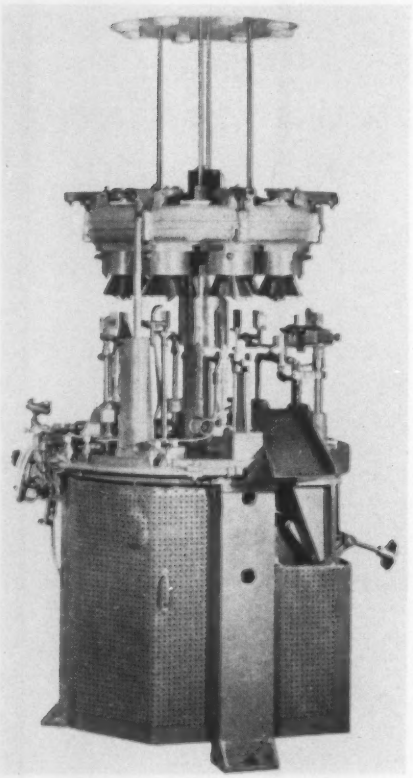

FLARE MACHINE

Hot-chill technique is used to cut flared necks for cathode ray tubes by a new machine which automatically makes the flare and then cuts it to proper length. Machine can cut glass tubing when flaring mechanism is locked out. All cut tubing for stems, tubulations, and necks used in electronic tube production can be produced. Large range of tubing diameters and lengths can be accommodated. Machine has ball bearing construction, precision barrel cam index, and forced feed oiling, operates with minimum maintenance. **Kahle Engineering Co.**, 1492 Seventh St., North Bergen, N. J.

Circle No. **20** *on Reply Card*

THE VALVE THAT REVOLUTIONIZED AIR CYLINDER OPERATION

You are looking at a cut-away section of the air control valve that has made air cylinder history — the Bellows Electroaire Valve. It, as much as any single factor, has been responsible for the terrific growth in the use of pneumatic circuits in production processes in the past ten years.

Why? - First of all — it is a complete air control unit. Not only does it direct the high pressure air to the desired cylinder port *instantly, without lag,* but it regulates and controls the speed of the air cylinder piston.

Second - while electrically controlled, it is not electrically powered. Instead of using heavy power solenoids to shift the valve, it uses the air it controls to do the work. Two sealed solenoids, hardly bigger than a thimble, act as "triggers" to release and direct the high pressure air.

Third - the small sealed solenoids act on only 8 volts of current. There is no danger of solenoid burnout (in fact the control units are guaranteed against burnout). Wiring requirements in interlocked circuits are simple. There is no electrical hazard to either operator or machine.

Fourth - the Electroaire Valve is compact. No bigger than a package of king-size cigarettes, it fits into crowded quarters, or on moving machines.

And finally — the Electroaire Valve is durable. Over a quarter of a million are in everyday use. Records of 30,000,000, 40,000,000 even 50,000,000 cycles without repairs of any kind are common.

Of course, the Electroaire Valve is a built-in feature of all electrically-controlled Bellows Air Motors, but it is equally suitable for use with any conventional air cylinder up to bores of 4½" - 5".

WRITE FOR THESE FREE BOOKLETS

Bulletins EV-310 — and CL-50 — detailed information on the Bellows Electroaire Valve and other Bellows "Controlled-Air-Power" Devices. Address:
The Bellows Co., Akron 9, Ohio
Dept. AU-1054

In Canada: Bellows Pneumatic Devices of Canada, Ltd.
4972 Dundas St., West, Toronto 18, Ontario

The Bellows Co.

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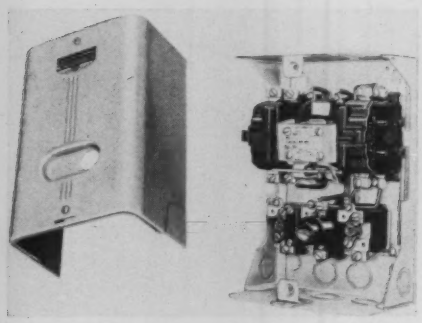
318-A

CONTROLLED-AIR-POWER FOR FASTER, SAFER, BETTER PRODUCTION

AUTOMATION NEW COMPONENTS



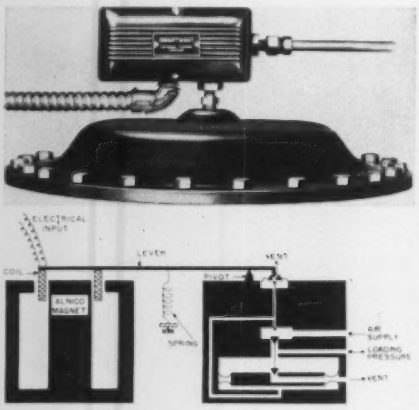
3-Coil Overload Motor Starter

A new starter offers 3-coil overload protection to prevent motor burnout sometimes experienced with 2-coil protection. For example, an open phase in the primary of the transformer in a wye-delta system results in one high and two low currents. When only two lines are protected, the high current line may be the unprotected line. In addition to added protection, 3-coil starter features an adjustable heater coil which allows four different ratings from a single coil by simply changing its position. Motor protection is within 3 per cent of usable motor load instead of 10 or 12 per cent under less coil protection. **Cutler-Hammer, Inc.,** 315 N. 12th St., Milwaukee 1, Wis.

Circle No. **21** *on Reply Card*

Power Relay Pneumatic System

Power relay is electropneumatic transducer designed for use with company's Autronic Control System. Relay takes electrical output from controller or manual control and converts it to an air loading pressure proportional to the electric current, thus utilizing the low cost and flexibility of air operated valves without the transmission lag normally encountered in completely pneumatic systems. Primary element transmitter converts process variables into a small ac voltage which is acted upon by actions of the controller. Controller's dc output, which is transmitted to power relay, is primarily governed by the transmitter but is continually modulated by the controller's proportional, reset and rate time actions. Relay operates on the null balance principle wherein a magnetic force is balanced

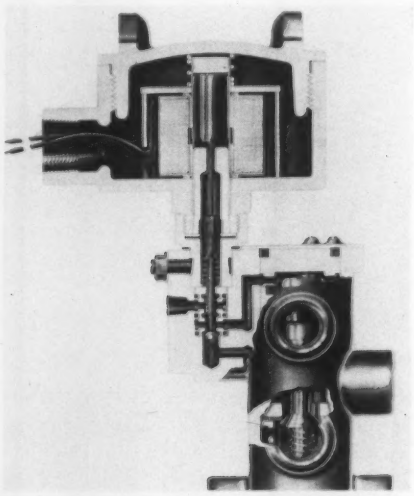


against force produced by air output pressure from the pneumatic pilot. A moving coil in a permanent magnet field is so adjusted that a 4 ma current produces 3 psi air loading pressure, and 8 ma current produces 15 psi output with a direct acting power relay. Higher air pressure ranges are available. **Swartwout Co.,** 18511 Euclid Ave., Cleveland 12, Ohio.

Circle No. **22** *on Reply Card*

Solenoid Air Valve

Unusual design feature of a new explosion-proof air valve is its extremely short solenoid stroke.

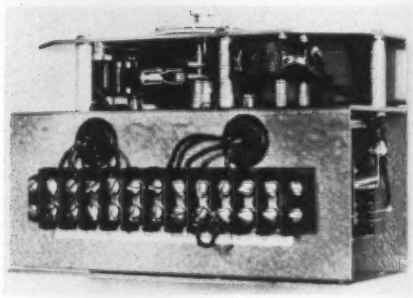


Short stroke combined with pilot operation eliminates problems of coil burnout. Poppet design with linear sealing contact on resilient seats makes both pilot and main valve self scavenging. Consequently, valve is particularly effective in extremely dusty installations such as cement batching equipment. Removable cover provides access to the solenoid. Coils are interchangeable so that valve can convert to any standard voltage by a simple coil change. **Barksdale Valves,** 5125 Alcoa Ave., Los Angeles 58, Calif.

Circle No. **23** *on Reply Card*

Automatic Timing Device

Particularly applicable to automatic factory operations, a motor driven timing device provides two separate timing circuits for start and stop cycles operating independently of each other irrespective of automatic reset. Unit consists of a continuously running synchronous motor, reduction gearing, a solenoid operated clutch controlled by the pilot circuit, and a load relay energized and de-energized by



two limit switches and activated by the cams. Pilot circuit is energized by any controlling device such as a switch, pressure sensor, or clock. Circuits are adjustable over a range of 20 to 165 seconds for both start and stop time delays, and delay periods up to 10 minutes are available. Device is known as Motorelay and is applicable to any pumping conditions, particularly where considerable backspin protection is necessary. If surge conditions develop and pilot circuit is energized and calls for starting or stopping of the pump, Motorelay immediately starts timing out the delay. When surge subsides and pilot circuit breaks, unit resets itself automatically and clutch cannot be activated until pilot circuit is again energized by another surge or by attainment of proper liquid level. Energization of load relay does not occur until liquid level has been constant for length of time set on dial. A pump prelubrication solenoid circuit is available. Voltage is 115 v ac ±10 per cent, or 230 v ac, and size is 4¾ x 3 x 6⅞-in. **Automatic Control Co.,** 995 University Ave., St. Paul 4, Minn.

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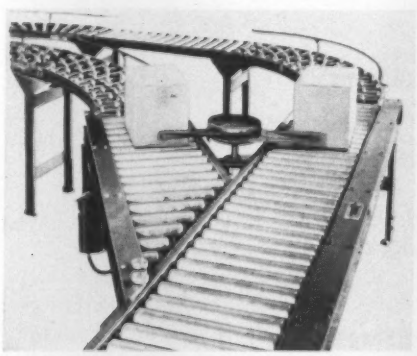

Converging Unit

Commodities from two conveyor lines can be fed into a single line without interference by means of "E-Z-Merger", a converging device. Unit can be used at various converging angles, with parallel conveyor lines, and with right angle transfers using belts, line rollers, or gravity conveyors. Adjustment for weight of commodities from 2 lb upward is accomplished by a tension feature. Ball bearings are used in all critical moving parts, and device is easily removed from its socket mounting. It can be raised or lowered to suit commodity height. Length of arm is easily changed by addition of a "flat" which allows convergence of a long and a short box into the same conveyor line. Unit will not lock if two boxes contact the arms at the same time since one commodity will always take preference. Arc of arm travel is approximately 90°. Space requirement is 10 in. in diameter and 4 in. high. **Standard Conveyor Co.,** 315 Northwest 2nd Ave., N. St. Paul 9, Minn.

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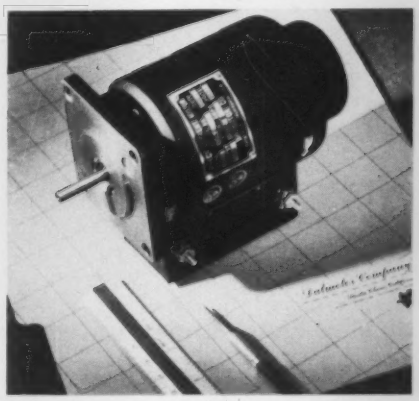
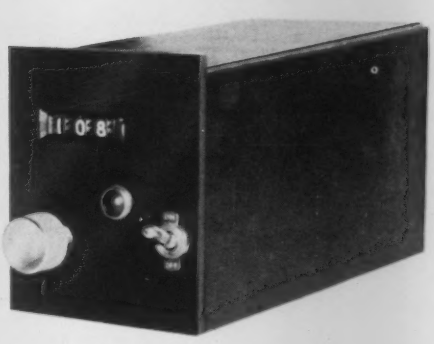


Constant Speed Motor

Engineered to meet requirements of a radar-antenna spin motor, this continuous duty motor can maintain a constant governed speed of 7100 rpm ±1 per cent from 24 to 30 v dc with load variations of ±30 per cent. Unit meets military specifications for temperature, pressure, and humidity in airborne equipment. Radio-noise filter on the motor frame, which carries power terminals for output voltage, counteracts radio interference. Rated at ⅛-hp and drawing 6 amp dc, the motor operates on 27 v dc and provides 9⅝-lb-in. locked rotor torque. Weight is 5½-lb. **Dalmotor Co.,** 1304 Clay St., Santa Clara, Calif.

Circle No. **26** *on Reply Card*



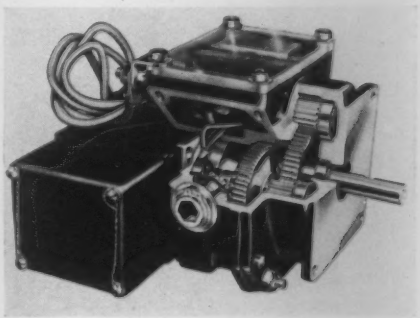
Miniature Numerical Indicator

High speed and easy legibility are featured in this numerical indicator for research, testing, and production applications. Unit provides accurate and direct reading of analog measurements without interpolation. High speed counter is geared to a servo motor and can be installed at a distance from the measuring point without lag difficulties. It is also adaptable to recording units where continuous readings must be available for batching and processing operations. **Streeter-Amet Co.,** 4101 Ravenswood Ave., Chicago 13, Ill.

Circle No. **27** *on Reply Card*

Automatic Control Actuator

Rotary actuator was developed originally for opening and closing camera doors and for wing-tip tank release in aircraft. Now adapted to electronic and automatic control, the actuator has a 110 v, single phase, 400-cycle reversible motor with brake. Unit has 96:1 ratio, 10,600 rpm input, and 12,000-cycle, 110 rpm output which develops 500-oz-in. torque. Normally provided with thermal protection, actuator can be supplied with overload clutch, emergency hand crank, and dc motor if necessary. **Western Gear Works,** P. O. Box 182, Lynwood, Calif.



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ANNOUNCING

Second Conference On Mechanisms

Cosponsored by Purdue University, Machine Design, and Automation

OCTOBER 11-12, 1954 **PURDUE UNIVERSITY**

Lafayette, Indiana

To promote better understanding, design and application of mechanisms in automatic machinery, MACHINE DESIGN, AUTOMATION and the Mechanical Engineering School of Purdue University have collaborated in bringing together a group of authorities on the most recent developments in this important field of design.

All automation designers and other engineering personnel interested in the design and development of mechanisms are cordially invited. For registration details write direct to M. M. McClure, Div. of Adult Education, Purdue University, Lafayette, Ind.

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PROGRAM

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Beveloid Gearing

A. S. BEAM, *Vinco Corp.*

Session 2—Mechanism Performance Analysis

Calculating Dynamic Characteristics of Mechanisms

B. E. QUINN, *Professor, Mechanical Engineering, Purdue*

Predicting Performance of High-Speed Mechanisms

G. A. NOTHMANN, *Armour Research Foundation*

Analysis of Mechanisms with High-Speed Photography

E. A. EDWARDS, *Eastman Kodak Co.*

Panel Group Discussions

What is Mechanism Synthesis?

Chairman A. S. HALL, *Prof., Mechanical Engineering, Purdue*

Mechanism Manufacturing Tolerances—How Good?

Chairman, P. T. EISELE, *Warner & Swasey Co.*

Session 3—Cam Design Problems

Cam Design and Manufacture

P. MAKER, *Bryant Chucking Grinder Co.*

Vibration Analysis of Cams

C. N. NEKLUTIN, *Universal Match Co.*

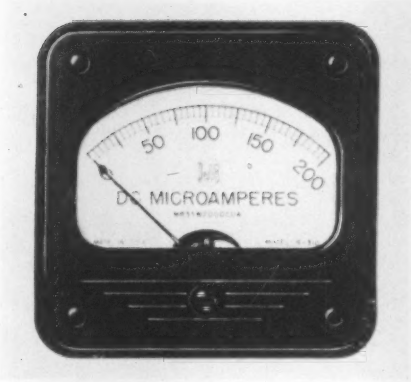
Session 4—Control Mechanisms

Straight-line Mechanisms

W. R. KEARNEY *and* M. G. WRIGHT, *Delco Radio Div., General Motors Corp.*

Proportional Control Mechanism

G. H. GICZEWSKI, *Bowser Inc.*



Indicating Instruments

A series of electrical indicating instruments which meet ASA specifications includes dc microammeters, milliammeters, voltmeters, and ammeters in a variety of ranges, resistance values, and sensitivity. Cases are 2½ and 3½-in. round or square, or rectangular. External pivots provide maximum accuracy and stability of adjustment between jewels and pivots, thus preventing pointer rocking and increasing the life of the bearing surfaces. Individual specifications can be accommodated. **DeJur-Amsco Corp.,** 45-01 Northern Blvd., Long Island City 1, N. Y.

Circle No. **29** *on Reply Card*

Motor Driven Generator

A two-phase winding generator is built for use in a combined unit of high torque-to-inertia ratio induction motor and linear drag cup generator. When one phase of generator is excited, the other develops output voltage proportional to speed. Linearity is dependent on voltage output desired and range of operating speeds. Motor and generator are both 115 v. Generator's voltage output at phase two is 3.5 v plus or minus 0.6 v per 1000 rpm, and residual voltage is 80 mv maximum, will not vary more than 20 mv when shaft is positioned through 360°. No-load speed is 3070 rpm counterclockwise and reversal time is 0.06 second. Unit is also available for operation on 400 cycles, or can be designed to specifications. **Electric Indicator Co., Inc.,** Springdale, Conn.

Circle No. **30** *on Reply Card*

Traveling Oven Thermometer

Self-contained recording thermometer passes through a traveling oven with bread or other baked goods, and at discharge end of oven offers a complete record of temperatures encountered at each point of the baking process. In operating position the thermometer is no higher than a loaf of bread. Immediate oven adjustments or repairs made possible by recorder assure uniform bakery products. Thermometer can be used in non-food baking applications whenever a low-clearance instrument is required for a continuous conveyor, traveling tray or traveling oven. **Bristol Co.,** Waterbury 20, Conn.

Circle No. **31** *on Reply Card*

DC Indicating Amplifier

Measurement of signals as low as 0.000,000,000,000,002 w is now feasible with a dc indicating amplifier, the first commercial instrument to be developed by a firm heretofore devoted to precision military instruments. Extremely low range is made possible by a second-harmonic magnetic converter which changes the dc input signal to an ac signal, replacing fragile mechanical converters and eliminating all moving parts. A high gain voltage amplifier magnifies the ac signal which is changed to dc by a demodulator.

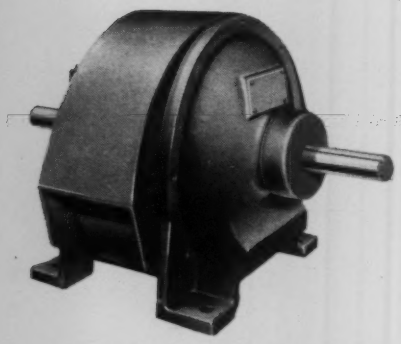
A power amplifier then increases power output to meter on instrument's face or to output terminals sufficiently to drive a recorder or control device. Self-contained power supply furnishes energy to all components. Highly accurate and reliable, this instrument has wide frequency response and great linearity, is immune to changes in line voltage. It will be employed to amplify any low level signal, to measure minute dc signals, to operate recorders and control devices, and to aid in null detection. **Doelcam Corp.,** 1400 Soldiers Field Rd., Boston 35, Mass.

Circle No. **32** *on Reply Card*

Electrical Counter

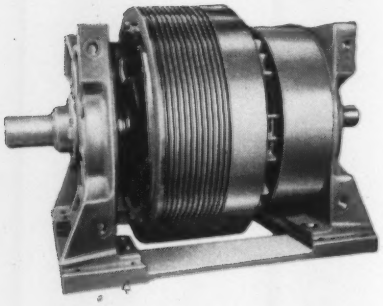
Instantaneous electrical reset is featured in a new line of electrical counters which can count up to 10 impulses per second in standard models, and as many as 25 impulses per second with special models. Reset to zero takes only 0.4 second, and reset voltage may differ from impulse voltage as required. Counters are available in four or five digit models, with or without housings, and are suitable for flush mounting. Compact units measure only 1⅜ x 2⅜ x 4⅜-in. **Landis & Gyr,** 45 West 45th St., New York 36, N. Y.

Circle No. **33** *on Reply Card*

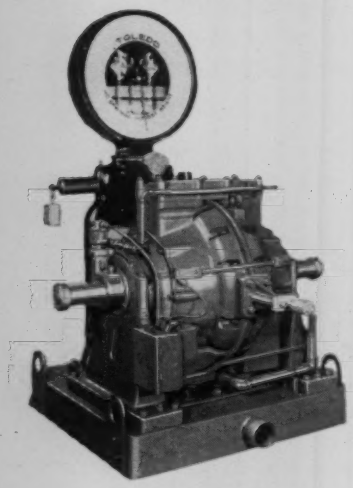


AIR COOLED COUPLINGS

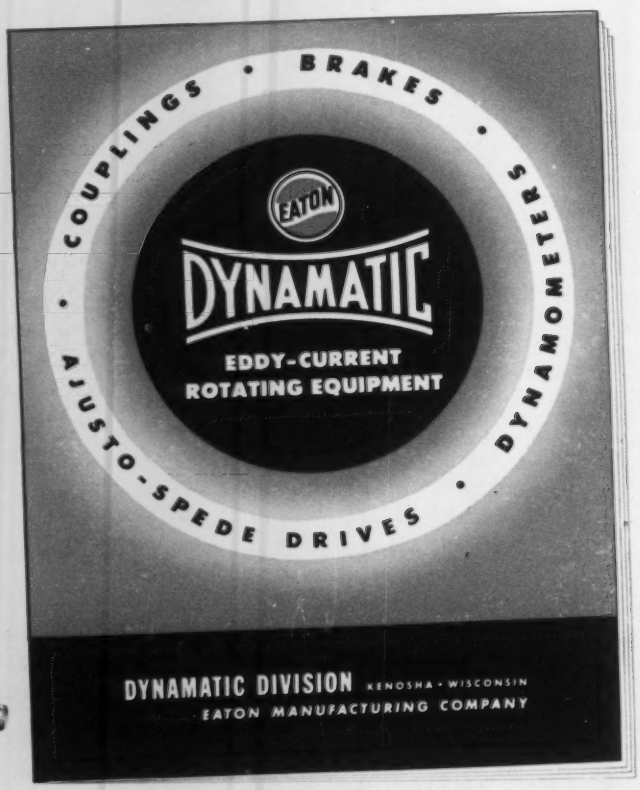
AJUSTO-SPEDE MOTORS

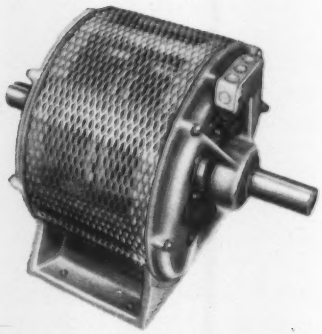


PRESS DRIVES

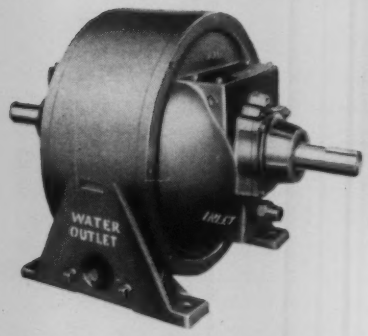


DYNAMOMETERS



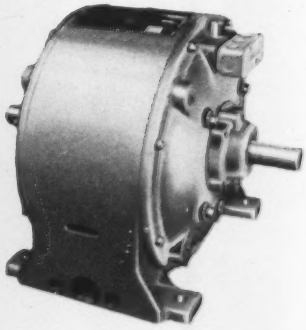


AIR COOLED BRAKES



LIQUID COOLED COUPLINGS

Our new booklet, "Bulletin GB2," describes and illustrates the basic Dynamatic Eddy-Current units, including the new Stationary Field Coupling. If you are interested in modern speed control, write for your copy.



LIQUID COOLED BRAKES

Speed Control Problems?

One of these Dynamatic Units may be the solution

Dynamatic Eddy-Current Couplings, brakes, clutches, Dynamometers, and Ajusto-Spede motors, in use today in practically every basic industry—in both plant equipment and end products—are proving the ideal solution to difficult speed control and testing problems. Advantages include rapid response, infinitely adjustable speed control, wide speed range, quiet operation, high full-load efficiency, low maintenance cost, adjustable speed from an AC power source. Write for your copy of the new Dynamatic Bulletin GB2 today.

DYNAMATIC®

DIVISION EATON MANUFACTURING COMPANY

KENOSHA, WISCONSIN • General Offices: Cleveland, Ohio

Cathode Follower

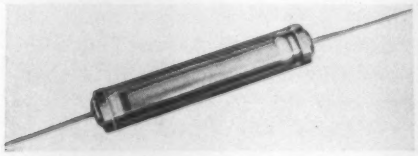
Dual-type cathode follower is designed to couple low output impedances, such as transmission lines, matrices or filters, with high input impedances, such as flip-flops, oscillators and voltage amplifiers. Two independent cathode followers are incorporated within this single miniature unit. Input grids may be connected to an external bias source or left floating, in which case the input can be coupled directly to the grids and utilize the high input impedance characteristics of the cathode follower. Resin capsulated, the unit is designed for plug-in operation and has 11-prong, octal-style plug. Each cathode output impedance is 100 ohms, tapped at 1000 ohms, with the signal amplitude at the tap approximately 65 per cent of the cathode signal amplitude. Output impedances of approximately 50 and 500 ohms are available by paralleling the two sections. **Walkirt Co.,** 145 W. Hazel St., Inglewood, Calif.

Circle No. **34** *on Reply Card*

Carbon Resistors

New line of carbon resistors is designed for high frequency application where high values of resistance are essential. They are ideally applied to closely matched units for computer network and to electronic equipment which is subject to extreme temperatures. In many applications the resistors can replace wire wound models. Hermetically sealed in glass and clad in humidity-proof casings, these resistors provide stability over long periods of time and freedom from variations due to climatic changes. Resistance range is 20 ohms to 200 megohms and wattage rate is ¼ to 2 w. **Phaostron Co.,** 151 Pasadena Ave., South Pasadena, Calif.

Circle No. **35** *on Reply Card*



Two-Switch Governor

A two-switch governor has been added to company's line of speed sensitive switches for standard distributor takeoff to accommodate gear or coupling drives or for standard tachometer drives. Governor consists of two snap action switches rated at 10 amp, 110 v ac. Unit can either close or open circuits at any rpm over 350, and each switch is individually adjustable up to 2000 rpm above specified set speed. **Synchro Start Products., Inc.,** Skokie, Ill.

Circle No. **36** *on Reply Card*

Motor for Actuators

Compact motor is well suited to intermittent duty on low or high speed, linear or rotary actuating mechanisms. Unit will turn 20,000 rpm at 1¾-oz-in. torque with 3.8 amp, 28 v dc. Locked rotor torque is 10½-oz-in.

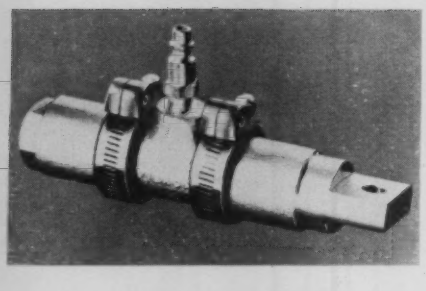
Automatic clutch brake applies 2-oz-in. brake torque to load and will disengage armature automatically upon power removal. Rotation is reversible and integral shielded leads provide electrical connections. Shaft can be plain, spline, keyway, or gear. **Dalmotor Co.,** 1304 Clay St., Santa Clara, Calif.

Circle No. **37** *on Reply Card*

Missile Ground Power Supply

Containing all necessary controls, including protective relays, for plug-in operation, this portable, 400-cycle, ac motor alternator power supply is designed for missile or flight ground power applications. Alternator is 4-bearing, V-belt driven, consequently is independent of motor. Inductor type alternator has no moving coils, slip rings, brushes, springs or other wearing parts. Excitation and field windings are stationary for minimum maintenance. Output is 7½-kva at 115 v, single phase, with 0.8 power factor. Frequency of 400 cycles per second is regulated to ±1 per cent by a magnetic amplifier, is available instantly by plugging unit into a standard ac power line. Motor equipment for 220 to 440 v, single or 3-phase operation is available. **American Electric Motors, Inc.,** 4811 Telegraph Rd., Los Angeles 22, Calif.

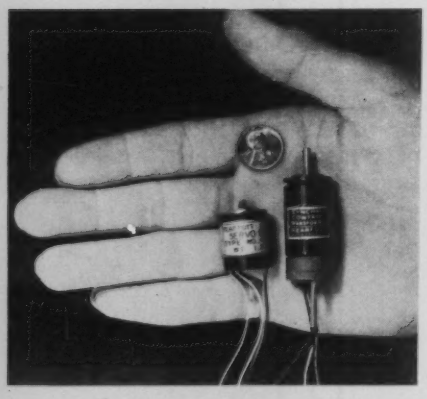
Circle No. **38** *on Reply Card*



Noiseless Pneumatic Vibrator

Muffler equipped pneumatic vibrators reduce processing time by vibrating small bins, chutes, hoppers, and screens to prevent arching, clogging, or sticking of inert bulk materials. Material flow is increased, downtime is reduced, destructive pounding is eliminated. A piston introduces compressed air alternately to opposite ends of cylindrical passage, delivering up to 5000 strokes per minute and operating on 30 to 140 psi line pressure. Supercharge is built in to increase operating air pressure 30 to 60 per cent above supply pressure, and vibration power 110 per cent. Vibrators are usually furnished with tong mountings, but special mountings to meet specifications can be incorporated. Vibrator can be furnished without muffler for adaptations where noise is not a consideration. **Vibron Div., Burgess-Sterbentz Corp.,** 3790 W. 150th St., Cleveland 11, Ohio.

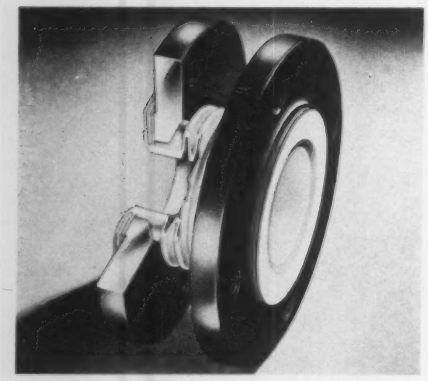
Circle No. **39** *on Reply Card*



"Penny-Size" Servo Components

Tiny servo motors and synchros, measuring only ¾-in. in diameter, feature straight-through bore and integral stator-housing construction for accuracy and quality performance. Highly corrosion resistant, these components have stainless steel housings, laminations, and ball bearings, and "potted" stator construction. Motor in illustration has 6500 rpm no load speed, 0.1-oz-in. stall torque, 1.5 w power input, 18 v input, and weighs only 1.2-oz. Transmitters, control transformers, and differentials have maximum error limits of 10 minutes from electrical zero to provide sensors and error detectors for the servo loop. Precision gear trains and a potted servo amplifier, the size of a cigarette pack, complete the servo system. **Kearfott Co., Inc.,** 1378 Main Ave., Clifton, N. J.

Circle No. **40** *on Reply Card*



Bellows and Companion Flanges

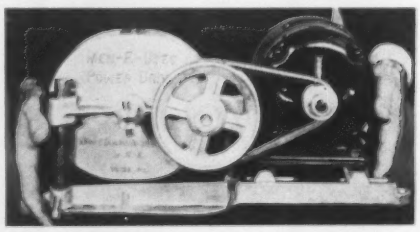
Teflon bellows with companion flanges are chemically inert and heat and corrosion resistant for operation with pressures up to 125 psi. New convolution form is said to give greater strength, longer life, and increased flexibility. Formation is retained at full free length, therefore bellows are subjected to minimum residual and working strain. Operating in a temperature range of −94 to 500° F, they will expand and contract in either direction with equal freedom of motion. Any pipe size from ½ to 12-in. can be fitted. French-type gasket construction provides efficient sealing at low flange pressure, and gasket insert material is asbestos or synthetic rubber. Bellows can be used with vibration dampeners, expansion joints and connectors, and for metering pumps, pressure accumulators, batching scales, and hydraulic systems. **Crane Packing Co.,** 1800 Cuyler Ave., Chicago 13, Ill.

Circle No. **41** *on Reply Card*

Oil and Moisture Separator

An oil and moisture separator for cleaning compressed air is available with or without a power regulator to assure steady and uniform air delivery at capacities up to 50 cfm. Combination separator and regulator handles pressures up to 135 psi from an air line carrying pressures up to 250 psi. Separating unit has an all metal, centrifugal type oil and water eliminator which does not need replacement or maintenance. Permanent filter can be removed easily for cleaning, and filter chamber is drained by a simple valve at bottom of unit. Separator can be installed in air lines supplying pneumatic tools or other units which require clean compressed air for operation. Separator is 15-in. long, 8½-in. wide when equipped with valves, and 8½-in. deep. **DeVilbiss Co.,** 300 Phillips Ave., Toledo 1, Ohio.

Circle No. **42** *on Reply Card*



Speed Reducer

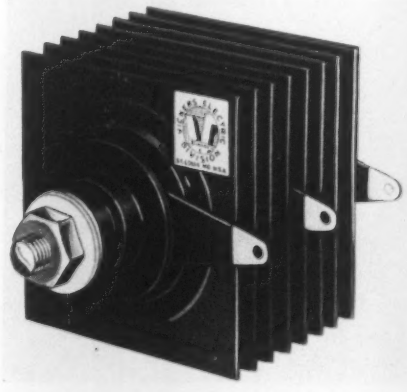
Two models of a variable speed reducer are available to meet power drive requirements of all ¼ to 2-hp motors. One model produces speeds of 1 to 150 rpm, while the second provides 20 to 750 rpm. **New Standard Div., U. S. Expansion Bolt Co.,** York, Pa.

Circle No. **43** *on Reply Card*

Heavy Duty Footswitch

Streamlined footswitch is designed for heavy duty operation activating all types of electronically operated equipment. Cast iron housing has a black wrinkle finish and a sponge rubber skid pad to prevent sliding. Wiring is easily accessible because removal of only two screws exposes entire inner mechanism. Switch is readily operated from a sitting or standing position, weighs only 2 lb. **Linemaster Switch Corp.**, 424 Woodstock Terrace, Woodstock, Conn.

Circle No. **44** *on Reply Card*



40-Volt Selenium Rectifier

Inverse cell rating of 40 v and ability to withstand surges up to twice the rated voltage are combined in a new selenium rectifier. In addition, the unit has low leakage of 2 ma per sq in. average and low inverse loss, with heating averaging less than 5°C. Dielectric quality is high. Rectifier operates in ambient temperatures as high as 125° C with no derating for 50° C. Life tests on the unit have passed the 25,000 hour mark. **Vickers Electric Div., Vickers, Inc.**, 1817 Locust St., St. Louis 3, Mo.

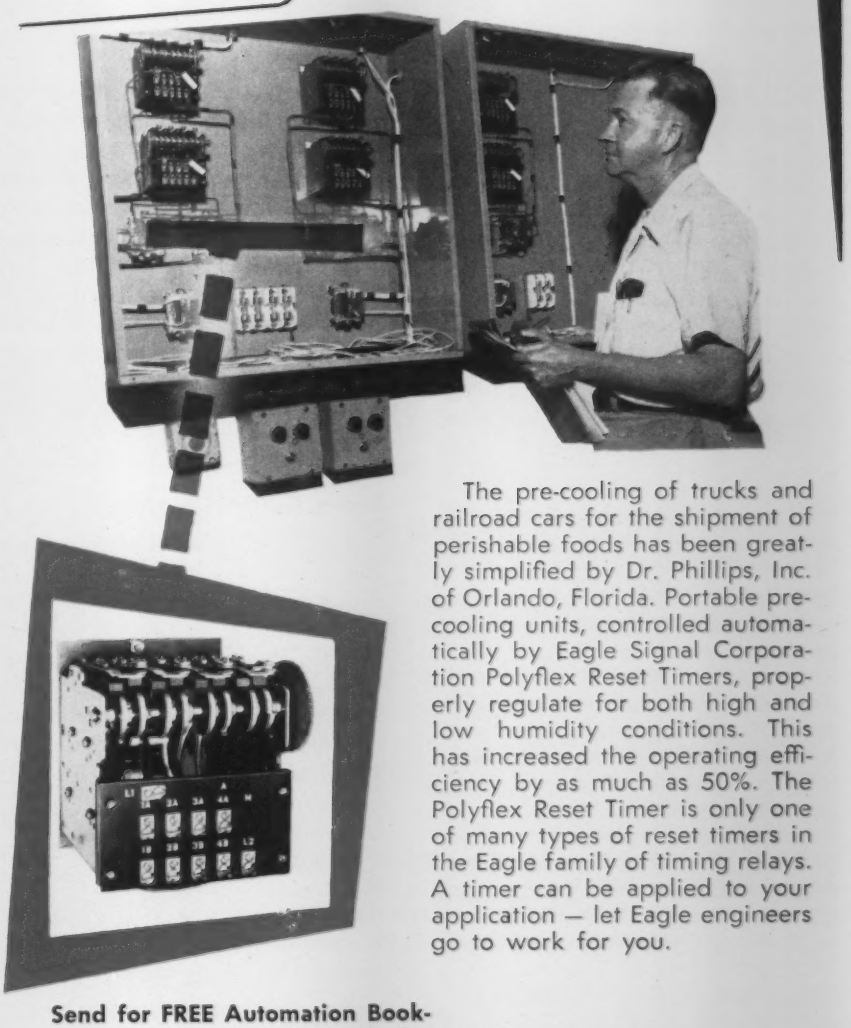
Circle No. **45** *on Reply Card*

YOU CAN DEPEND ON

EAGLE FOR GREATER PROFIT

Automation STARTS WITH EAGLE Timers

AUTOMATIC DEFROSTING



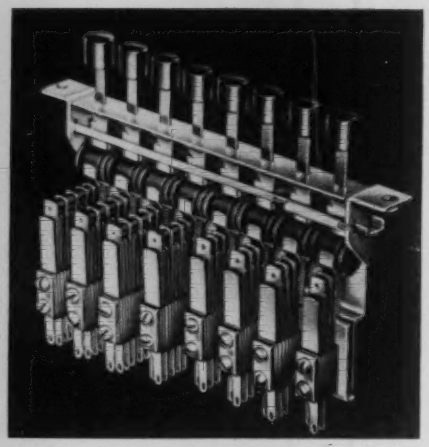
The pre-cooling of trucks and railroad cars for the shipment of perishable foods has been greatly simplified by Dr. Phillips, Inc. of Orlando, Florida. Portable pre-cooling units, controlled automatically by Eagle Signal Corporation Polyflex Reset Timers, properly regulate for both high and low humidity conditions. This has increased the operating efficiency by as much as 50%. The Polyflex Reset Timer is only one of many types of reset timers in the Eagle family of timing relays. A timer can be applied to your application — let Eagle engineers go to work for you.

Send for FREE Automation Booklet "See what timing can do for you."

Industrial Timers by EAGLE

EAGLE SIGNAL CORPORATION MOLINE, ILL.

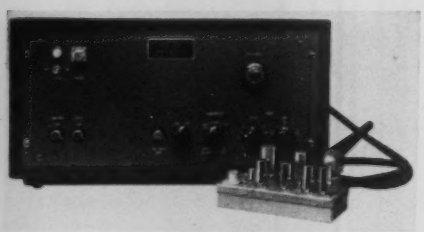
EAGLE TIMERS SAVE TIME, SAVE MONEY



Interlocking Station Switches

Two multiple station, interlocking pushbutton switches, Series 5700 (illustrated) and Series 5900, are available in capacities of four to twelve stations with various contact assembly combinations. Since all stations interlock, act of depressing any button automatically releases any other previously operated button. New switches can be used on communication equipment, alarm and signalling apparatus, radio and television broadcast and control equipment, test panels, industrial process control units, railway communications systems, electronic devices, controls, and instruments. **Donald P. Mossman, Inc.,** Brewster, N. Y.

Circle No. **46** *on Reply Card*



Linear Amplifier, Preamplifier

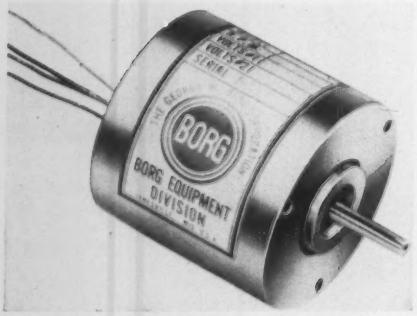
Linear amplifier is designed for stability when used with scintillation and proportional counters and other nuclear detection devices. Pulse height discriminator is controlled at high level output by a ten-turn helical potentiometer. Hermetically sealed transformers prevent high frequency transients when rectifier switches from one half cycle to the other. Another transformer supplies filament voltage to preamplifier to prevent power transformer's pulses from transmitting to preamplifier input. Scintillation spectra can be taken in the range of 22 KeV with 75 MeV background with little or no distortion. Front panel receptacle allows signals to feed directly into output feedback loop, thus facilitating pulse height analysis. Controls are a power switch, a coarse gain control with six steps, a fine gain control between the six steps, a three-position bandwidth switch, a delay line (2 Mc) of 0.5 Mc and 0.1 Mc, a pulse height selector, and a use-test switch. Maximum linear signal of high level output is 90 v into 1000 ohms, while low level maximum is 2.5 v.

Preamplifier, designed for use with amplifier, provides added gain required for use with ionization chambers and other high impedance, low level radiation detectors. Required filament voltage from amplifier is 6.3 v ac, 0.7 amp. Gain is 30, rise time less than 0.2 microsecond. **Atomic Instrument Co.,** 84 Massachusetts Ave., Cambridge 39, Mass.

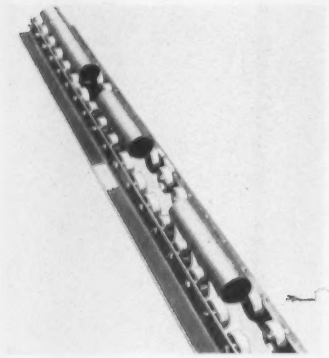
Circle No. **47** *on Reply Card*

Servo Control Motor

A servo control motor is 2-phase, induction type with 115 v, 400 cycles per second, 5500 rpm no-load speed. Originally designed for use with company's line of potentiometers, this compact unit may be adapted as a precision component in many servo applications. Minimum locked rotor torque is 0.82-oz-in. in either direction when operation is at 115 v. Three screws through the housing will mount the motor firmly. Size is 1½-in. diam, 1½-in. long with ½-in. shaft extension. **Borg Equipment Div., George W. Borg Corp.,** Janesville, Wis.



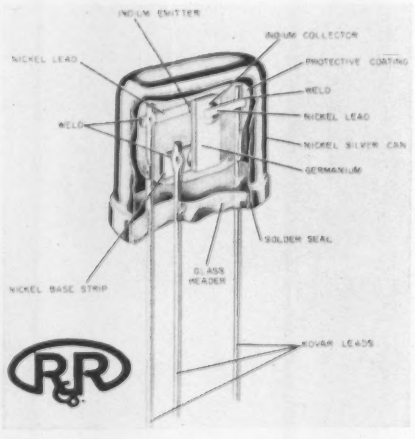
Circle No. **48** *on Reply Card*



Single Rail Conveyors

Wheelrail conveyors are available singly or in multiple units for use in plants, warehouses, terminals, where a variety of containers is handled. Available in 5 and 10 ft sections, conveyor has wheels which have been grease-packed for life. Bolted to table or floor, or used on special stands available from the manufacturer, the conveyors are easily installed and readily relocated at any time to suit varying conditions. Cylindrical and odd shaped pieces can be accommodated by spacing rails to fit. **Sage Equipment Co.,** 30 Essex St., Buffalo 13, N. Y.

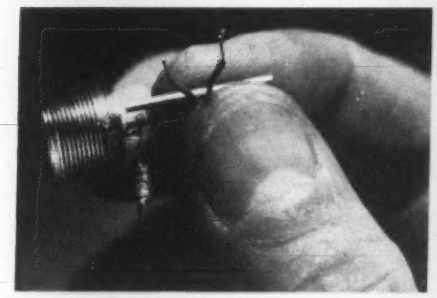
Circle No. **49** *on Reply Card*



Junction Transistors

Contamination free, light and moisture-proof operation in low level audio circuits is function of a new line of small, economical junction transistors. The new line features hermetically sealed metal casings, and entire unit measures only 0.325 x 0.328 x 0.344-in. **Seletron & Germanium Division, Radio Receptor Co., Inc.,** 251 West 19th St., New York 11, N. Y.

Circle No. **50** *on Reply Card*



Fluctuating Pressure Transducer

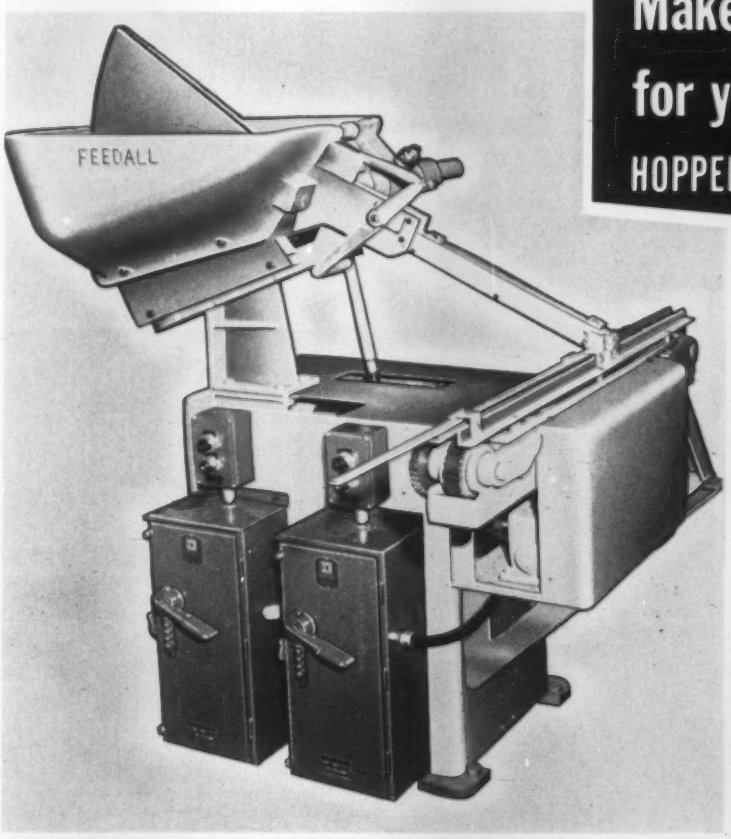
Bonded strain gage transducer is a hollow threaded cylinder with a taut diaphragm at one end and electrical and pressure connections at the other. Reference pressure tube is brought out directly with electrical terminals to permit unit to be threaded into flush mounting from either direction. A 120-ohm gage is bonded to inner surface of diaphragm and wired to electrical terminals. Sensing diaphragm is flush with surface against which pressure is to be measured to provide a resistance change which is a true representation of pressure fluctuations and to eliminate phase and amplitude errors. Transducer is available in seven pressure ratings ranging from 2½ to 200 psi, operates in temperatures of −40 to 250° F, and has 8000 cycles per second diaphragm resonant frequency. Standard unit is ½-in. in diameter, and ¼ or ⅜-in. long, weighs 4.5 grams. External metal areas are gold plated for corrosion resistance, and units are said to be free from shock and acceleration effects. Transducers are used to investigate fluctuating pressure in research, experimental, and industrial applications. **Electronic Engineering Associates, Ltd.,** 923 Brittan Ave., San Carlos, Calif.

Circle No. **51** *on Reply Card*

Variable Frequency Power

Variable-frequency power package covers frequency range from 380 to 420 cycles. Fully enclosed in a steel cabinet, unit is mounted on rubber tired casters for mobility. Power factor is 0.9, 1½ kva. Three phase output is 115/200 v, and voltage is held constant by an electronic regulator within plus or minus 1 per cent over full frequency range. A variable speed drive has control wheel extending from front panel. Drive motor operates on 220/440 v, 3-phase, 60 cycle ac. No moving parts other than the laminated inductors, rotating shaft and ball bearings are in the four bearing, belt-driven, inductor alternator. Other frequency ranges are manufactured in similar units. **American Electric Motors Inc.,** 4811 Telegraph Rd., Los Angeles 22, Calif.

Circle No. **52** *on Reply Card*



Make FEEDALL Headquarters for your AUTOMATIC FEEDERS

HOPPER-ROTARY-VIBRATORY-BLADE FEEDS

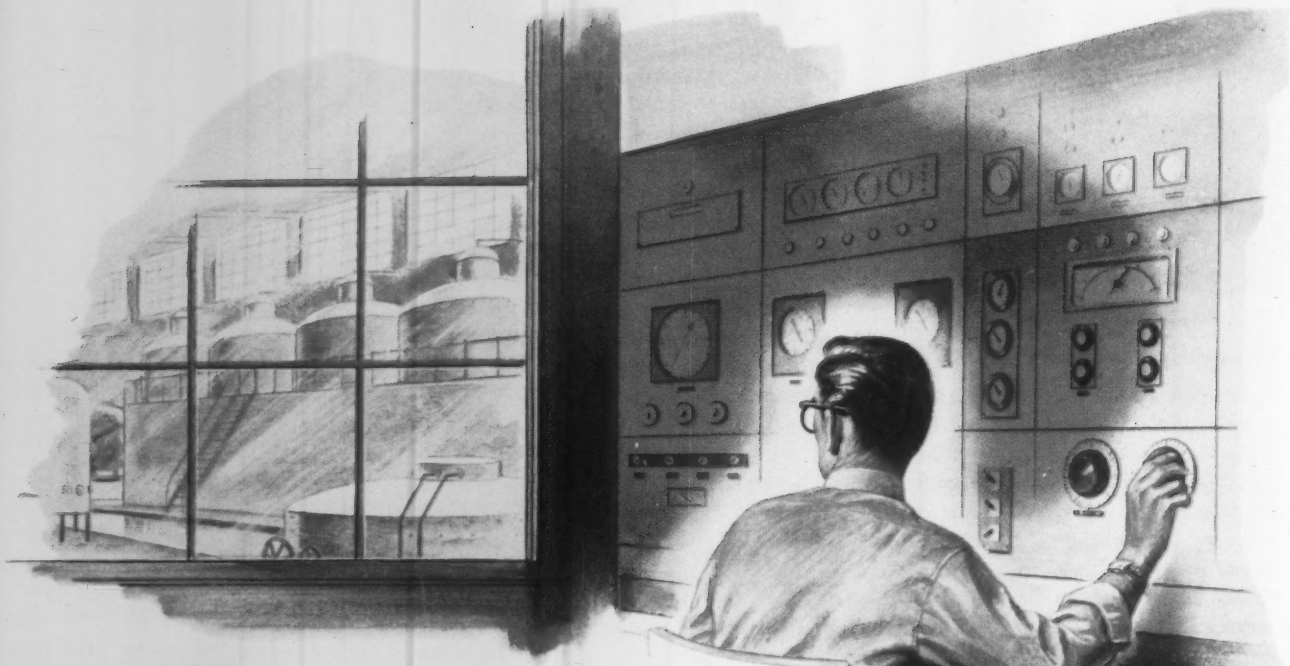
ILLUSTRATED is another of a variety of units, automatically feeding gear blanks to a centerless grinder, using a FEEDALL Automatic Hopper Feed and Transfer Conveyor combination. Blanks are picked up by the oscillating center board, or blade, selected and fed down a chute at right angles to the conveyor. The conveyor then transfers the positioned gear blanks to the work rest of the centerless grinder. Both hopper and conveyor have individual variable speed drives and motor controls.

Send samples or prints with your production requirements and let us tell you how FEEDALL Feeders can help you.

FEEDALL

MACHINE AND ENGINEERING CO.

WILLOUGHBY, OHIO, U.S.A.



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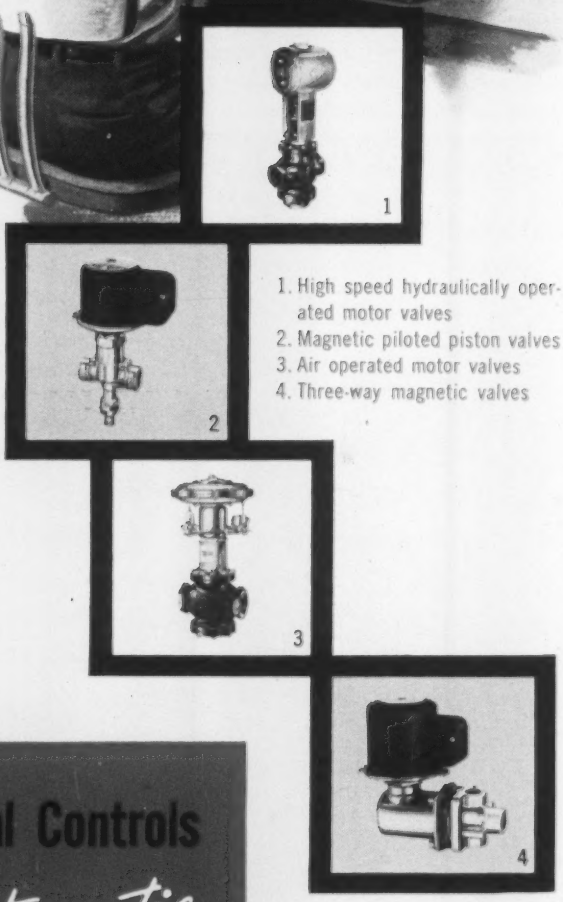
His confidence is in control—the complex, automatically timed control of program and sequence. It makes him complete master of the vast processing operation underway before him. He knows the engineered performance is taking place as scheduled—unmarred by human fallacy or fatigue . . . unaffected by judgments less than perfect, by skills unlearned, by fallible hands, by lapses of attention. He knows that flow and level are on the mark, pressure perfect, temperature pin-pointed, timing true to the split-second operation—all automatically. And the famous red shield of General Controls on the automatic devices which make this miracle of technology possible is his assurance that everything is under control—always, in all ways. He is confident—and you can trust his confidence!



1. High speed hydraulically operated motor valves
2. Magnetic piloted piston valves
3. Air operated motor valves
4. Three-way magnetic valves

GENERAL CONTROLS

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General Controls
Automatic Valves

new catalogs..... latest literature

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Plug Valve Actuators

Ledeen Mfg. Co.—Tandem type actuators for valves requiring high torques for operation, and new floating bar type actuators for valves requiring lower operating torques are subjects of an 8-page bulletin. Actuators are pneumatically or hydraulically operated for remote control and automatic processing applications, can be installed on new valves or existing valves already in service. In addition to an actuator selection table, bulletin gives typical applications, dimensions and weights, and illustrates various mountings and accessories.

Circle No. 53 on Reply Card

New Tube for Flow Metering

Builders-Providence, Inc.—Dall flow tube, a new, short differential producing, metering device is subject of a 16-page engineering bulletin. Flow tube is said to have the lowest permanent loss of head of any known velocity-increasing differential producer. Information includes recovery characteristics, accuracy, applications, range, flow formula, laying length, and working pressure. Sections discuss installation, power consumption, effect of approach and downstream piping and fittings, and location of instruments. Tables and graphs are included to aid in selection of the proper flow tube and secondary instruments.

Circle No. 54 on Reply Card

Broaching Booklet

Colonial Broach Co.—"Chips Tell the Story" contains in 12 pages a general discussion of broaching processes and equipment for producing parts rapidly. Comparison is drawn between cutting action of single and multiple-point tools and broaching tools, and illustrations of numerous broaching applications are included.

Circle No. 55 on Reply Card

Automatic Washer for Castings

International Conveyor & Washer Corp.—An automatic indexing, fixture type, three stage industrial washing machine processes 400 castings per hour, externally and internally, and maintains cleanliness of solutions automatically. Four-page bulletin describes machine and its components, complete cleaning cycle, and gives specifications.

Circle No. 56 on Reply Card

Machine Tool Fixtures

Swartz Tool Products Co.—"Advancing Automation" is title of a new 8-page bulletin describing company's complete services to builders of machine tools, and its facilities for the design and construction of precision work-holding fixtures. Typical fixtures for standard, single station, rotary index, trunnion index, and transfer machines are illustrated with factual data on each.

Circle No. 57 on Reply Card

Automation Timers

Eagle Signal Corp.—Application of timers in design and function of machines for automatically handling, machining or processing parts and materials is discussed in a 12-page illustrated booklet. Timers are discussed in two categories, reset or repeating cycle. Seventeen specific models are treated in detail.

Circle No. 58 on Reply Card

Electronic Computer Elements

George A. Philbrick Researches, Inc.—A revised 8-page catalog of electronic analog computing devices features two series of computing components. K3 series includes integrating, differentiating, adding, coefficient, augmenting integrator, augmenting differentiator, unit-lag, bounding, backlash, inert-zone, squaring, square-root, and absolute-value components. K4 series features dynamic, multiplying, and functional elements. Block equations and diagrams are set up as sample problems.

Circle No. 59 on Reply Card

Hydraulic Components

Hydraulic Press Mfg. Co.—Nine separate catalogs are devoted to distinctly separate components in company's hydraulic line. Each catalog contains all basic data needed by engineer including photos, cross section views, dimensions, operating control diagrams. Subjects of individual catalogs are: pumps, motors, and power units; air and oil hydraulic cylinders (four catalogs); valves and flange connections; valves and gasket mountings; valves and threaded connections; and an engineering manual.

Circle No. 60 on Reply Card

Instrument Control for Hopper Scale

Richardson Scale Co.—A complete weighing, indicating and recording cycle is described in booklet on instrument system for use with hopper scales. System features interlocking switches, time delay before full balance printing, partial draft printing, follower dial accuracy, and dust control provisions. Dimensional engineering drawing and table listing headroom requirements for hopper scale included.

Circle No. 61 on Reply Card

Highlights in PEC Progress

Patterson, Emerson, Comstock, Inc. Pictures and descriptions of company products and achievements comprise this 44-page bulletin. PEC electrical construction installations in boiler houses, switchyards, substations, arc furnaces and strip mills in operation are among illustrations. A list of PEC's principal clients is also included.

Circle No. 62 on Reply Card

Hydraulic and Air Cylinders

Hanna Engineering Works — New line of fluid power cylinders features large capacity to size ratio, corrosion resistance, minimum friction, interchangeable components, positive cushioning, air operation up to 250 psi, and hydraulic operation up to 750 psi. Capacity charts, mounting installations, dimensions, and accessories are set forth in a 14-page catalog, as well as a check list of considerations to be taken in cylinder application and ordering specifications.

Circle No. 63 on Reply Card

One-Pan Balance

Wm. Ainsworth & Sons, Inc.—"Right-A-Weigh" is a one-pan balance for accurate substitution weighing with constant sensitivity. Weight is handled mechanically by knobs on the case which operate weights from 200 grams to 100 mg. Total of weights is read directly from counters on front of the case. Four-page bulletin offers specifications, price, and description.

Circle No. 64 on Reply Card

Vibration and Shock Mountings

Robinson Aviation Inc.—Resilient, primary load-carrying cushions of knitted metal wire, called Met-L-Flex, form basis of new vibration and shock control. Four-page bulletin shows how units will stop vibration, eliminate shock, and reduce noise, in addition to illustrating typical mounting systems complete with engineering data. Mountings are recommended for delicate precision instruments, motors, engine mountings, large machine tools, press drives and drop hammers.

Circle No. 65 on Reply Card

Parts for Production Machinery

A. & A. Mfg. Co.—Fourteen methods of fabricating pliable parts for automatic production equipment are illustrated in data sheet. These include dust covers, sleeves, boots, diaphragms, etc. Suggested materials are 0.033-in. for high speed flexing purposes, 0.050-in. for toughness or self-supporting rigidity, and solid neoprene block for shock absorption.

Circle No. 66 on Reply Card

Telemetering Booklet

Bristol Co.—Almost 100 photographs illustrate applications of a line of Metameter telemeters to measurement and transmission of pressure, flow, liquid level, mechanical motion, electrical units and totalized power load in a 44-page booklet. Telemetering over telephone circuits, carrier current, and private wires is featured, as well as microwave, time multiplexing, and selective calling. Metagraphic recorders and indicators for use as metameter receivers on graphic panels and consoles are included.

Circle No. 67 on Reply Card

Record Playback Control

General Electric Co.—Illustrated 6-page bulletin describes system of recording motion on magnetic tape and playing it back for automatic programming of production machines. Recording is taken by selsyns (synchros) coupled to feed motors to report motors' angular positions to tape by electrical signals. Recording can be taken of operator's manual operation of machine, or, for more complex parts, of motion of a tracer head. Still in planning stages are recording systems taken from line drawings requiring no machine setup, and operation from digital information which will be punched on paper tape.

Circle No. 68 on Reply Card

(Continued on back side)

new catalogs..... latest literature

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Automatic Spray for Die Press

Hamilton Automation Inc.—Die presses can be equipped with an automatic spray unit which will spray compound automatically at each press stroke in metered amounts to critical locations. Press need not be stopped to spread compound on lower part of the die. compound is not wasted, and die life is increased. Folder is available describing unit and components.

Circle No. 69 on Reply Card

Comprehensive Conveyor Parts Catalog

Link-Belt Co.—A new 340-page catalog has thumb index to provide easy and rapid selection of standard products. Major product classifications include chains and sprockets for conveying, elevating and power transmission; enclosed gear drives and variable speed drives; ball and roller bearings, babbitted bearings, pulleys, gears, clutches, and couplings for power transmission; components for screw, belt,' oscillating, and bucket conveyors. Capacity charts and dimension tables aid in selection of products.

Circle No. 70 on Reply Card

Automatic Storage Handling

Chicago Tramrail Corp.—Automatic cranes and tracks for materials handling utilize maximum storage area and minimize aisle space and labor, as pointed out in bulletin TRC-101. Cranes can be top running or underrunning, will move up, down, forward, reverse, clockwise and counterclockwise. Many examples of operating units are shown.

Circle No. 71 on Reply Card

Creative Engineering

W. F. and John Barnes Co.—Creative development, design and construction of any specialized mechanical, hydraulic or electrical equipment to individual specifications is company's function, as described in 32-page booklet. Examples of special machine tools, handling and conveying equipment, sorting, counting, assembling and gauging equipment, and electrical controls are illustrated. Booklet includes photos of ordnance plant, said to be close approach to automatic factory of the future, which company designed, built and operated for the government.

Circle No. 72 on Reply Card

Hydraulic Packing Protection

Hydraulic Accessories Co.—"Seal-Guards", metallic rod wipers, are installed on hydraulic packings to remove sand, grit, paint or chips before they reach internal hydraulic parts. Data sheet gives ordering information and installation instructions, as well as description and illustrations.

Circle No. 73 on Reply Card

Pressure Control Valve

Minneapolis-Honeywell Regulator Co. — A pressure balanced diaphragm motor valve designed for accuracy and speed of response in pressure control is subject of specification sheet 425. Valve is springless, double-seated, with downstream take-off connected back to lower pressure chamber of the top works. Providing highly sensitive control of outlet pressure, valve handles liquids or gases, is particularly applicable to pressure reduction of fuel in jet engine test cell fuel lines. Specifications, mounting dimensions and ordering information included.

Circle No. 74 on Reply Card

Metallic Film Potentiometers

Potentiometer Div., Fairchild Camera & Instrument Corp.—"General Design and Performance Characteristics of Film Type Potentiometers," a paper presented at the 1954 Electronic Components Symposium, is available to all interested engineers. Outstanding features of a metallic film type resistance element in potentiometers include infinite resolution, high temperature operating capability, and a wide resistance range in small diameter units.

Circle No. 75 on Reply Card

Pneumatic Controllers

Fischer & Porter Co.—Stack type pneumatic controllers, for process variables such as flow rate, liquid level, viscosity, pressure, temperature, and vacuum, are illustrated with cutaway photographs, schematic diagrams, and dimensional drawings in a 12-page catalog. Specifications, controller selection guide, controller response actions, and accessories are included. Units can be case, field, or valve mounted.

Circle No. 76 on Reply Card

Design of Saturating Servomechanisms

Cook Electric Co.—A 16-page booklet entitled, "Design Considerations of a Saturating Servomechanism" takes general principles underlying multiple mode control of servomechanisms and determines optimum values with which the designer can synthesize a saturating linear servo system that will have a response approaching that of the optimumly switched servo. Relationship between saturated and unsaturated regions is shown, and method whereby the effects of torque and velocity saturation can be considered when choosing the linear parameters. Effects of various damping factors upon the saturating response are described by phase plane analysis. Phase plane allows determination of optimum response of system for a given motor and load.

Circle No. 77 on Reply Card

Plastic Heat Sealing for Packaging

Vertrod Corp.—Heat sealers which weld thermoplastic films, heated by short, powerful heat impulse and then cooled under pressure, are subject of illustrated 4-page bulletin. Machine consists of two metal bars which act as jaws. Pressure bar has soft rubber surface, while heater bar consists of an insulated resistance wire. Jaws close over film, current impulse is applied, weld cools under pressure and develops full strength. Heat sealing may be used on manual or foot operated sealers, on power-driven bag sealing and bag making machines, and fully automatic packaging equipment. Various models and prices listed.

Circle No. 78 on Reply Card

Variable Speed Drive and Control

U. S. Electrical Motors Inc.—An automatic drive and control for use in operations involving variables such as temperature, pressure, speed, liquid level, weight, tension, and position are known as Varidrive and Varitrol. Four-page bulletin gives operating data and applications which include program and machine tooling control. Varitrol is basically a pneumatic amplifier composed of a power and a signal system. High pressure power system operates piston in the cylinder, is controlled by a low pressure signal system. Drives are available from ¼ to 30 hp with speeds from 14 to 14,000 rpm.

Circle No. 79 on Reply Card

Automated Machine Tools

Turchan Follower Machine Co.—Three automation systems offered by company are (1) automatic control systems for machine tools already in use, (2) entirely new servo controlled machine tools, and (3) servo control systems built into products of major machine tool manufacturers at their plant. Well illustrated and diagrammed 24-page booklet discusses principles of automation, shows typical control applications, and features two specialized tracer-controlled machines now in production—the hydro-router for production routing and milling, and the vertical contouring lathe for reproducing irregular contours.

Circle No. 80 on Reply Card

Study of Automating Plants

T. A. B. Engineers, Inc.—An engineering firm has published a concise, 4-page booklet to aid executives in understanding the current significance of automation and in determining whether their factories can be adapted to it. "Cut Costs with Automation" discusses the history and evolution of automation, and contains a check list questionnaire to help evaluate reader's own company, plant and product to determine the practicability there of automation or partial automation.

Circle No. 81 on Reply Card

Roller Gear Drives for Indexing

Ferguson Machine & Tool Co., Inc.—Roller gear drives for use in precision indexing of automatic production machinery are described in a 24-page catalog. Drives may be applied to dial, carrier chain, feed roll or oscillating indexing systems. Catalog discusses selection of drive, calculation of load requirement (illustrated by sample problems), designing of installation, and detailed instructions on how to order a drive unit. Complete tables on load rating and on dimensions for entire drive unit or components, as well as price lists and estimate sheets, are attached.

Circle No. 82 on Reply Card

Relays

Magnecraft Electric Co.—Complete line of relays, including long and short form telephone type, sub-miniature, latching and low capacitance, and open, plug-in, hermetically sealed relays, is described with engineering and dimensional data in new catalog.

Circle No. 83 on Reply Card

save time

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Automatic Speed Control

Reeves Pulley Co.—Hydraulic and pneumatic controls, mechanical automatic controls, automatic control to maintain tension of web materials, acceleration controls, Conoflow control (a specialized pneumatic control), differential and electric remote controls can be combined with one of two variable speed units to solve any control problem, according to a 24-page booklet entitled, "Join the Swing to Automation". These units will control tension, acceleration, deceleration, velocity and peripheral speed, will synchronize one or more machines and maintain uniform temperature and pressure.

Circle No. 84 on Reply Card

Precision Machine Tool Attachments

Standard Electrical Tool Co.—Many variations of traverse, slides, feeds, tables, and spindles are offered on a "do-it-yourself" basis to manufacturers who wish to convert old machine tools or to design their own special-purpose tools. Units are available for manual, pneumatic or hydraulic operation.

Circle No. 85 on Reply Card

Cyclo-Monitors

Counter & Control Corp.—Engineering data catalog covers a line of circuit controlling preset counters which will count revolutions, strokes, or electric impulses, will transfer a switch when a preset count is reached, hold switch for predetermined count without interrupting counting operation, and return switch to normal position.

Circle No. 86 on Reply Card

Positioning for Radial Drills

Fosdick Machine Tool Co.—Automatic positioning table, available for use on radial drills, is described in a 4-page bulletin. Table employs two simple duplicating bars to give automatic and exact reproduction of precision drilled, bored, tapped and reamed parts without use of jigs or stop adjustments.

Circle No. 87 on Reply Card

Windowless Flow Counter

Atomic Instrument Co.—Counting of alpha and beta particles in solid samples, and geiger and proportional counting are primary functions of a new windowless flow counter described in Bulletin 952. Rapid changeover of samples, gas-tight chamber, and counting rates independent of variations in gas flow are featured.

Circle No. 88 on Reply Card

Automation In Industry

Associated Metal Fabricators, Jersey Sheet Metal Products, Inc.—A study of increasing production efficiency and lowering costs through automation demonstrates latest production line techniques by a selection of mechanized equipment. Booklet covers industrial racking equipment and special heavy duty metal working machines.

Circle No. 89 on Reply Card

Automatic Press Unloading

Sahlin Engineering Co.—A 16-page bulletin discusses and illustrates a line of automatic unloaders, Iron Hands, which are installed on presses and take workpiece directly from the press after stamping. Self-contained unloaders derive their power from their own air cylinders.

Circle No. 90 on Reply Card

Combustion Control Valves

Eclipse Fuel Engineering Co.—Data sheet describes line of valves for combustion controls. Equipment includes a Lock-Tite safety shut-off valve for protection against gas, air or electrical failure, lever handled gas cocks, blast gates, temperature valves, "DO" solenoid valves, motorized valves, and governors.

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Cleveland 13, Ohio

Readers Service Dept.

New Catalogs & Literature

Miniature Actuator Motor

Dalmotor Co.—Engineering data, dimensional drawing, performance graph, and electrical and physical characteristics for an actuator motor are set forth in a data sheet. This motor is a series-wound, 25 w, miniaturized unit, and is capable of 20,000 rpm. It is designed primarily as a driving element in low or high speed linear or rotary actuator applications.

Circle No. 92 on Reply Card

Electrical Contact Rivet Slide Chart

Fansteel Metallurgical Corp.—A copyrighted slide chart is available to facilitate selection of solid or composite rivet type electrical contacts. Maximum and minimum dimensions for head thickness, shank diameter, and shank length for a given rivet head diameter can be determined for rapid and economic production of contact rivets on automatic heading machines.

Circle No. 93 on Reply Card

Precision Cams

Ford Instrument Co. Three dimensional cams, with tolerances to $\pm$0.0005-in. and single input cams with tolerances to $\pm$0.0001-in. are described in this four-page bulletin. "Three-D" cams can be used for jet fuel supply as a function of rpm and temperature; AA ballistic corrections as a function of elevation angle and range or time of flight; bomb characteristics as a function of air speed and altitude or dive angle; and magnetic variation as a function of latitude and longitude. Functions cut into single input cams are: squares, roots, reciprocals, trigonometric functions, logs, reciprocals of square roots, combined trigonometric functions, and empirical functions such as ballistic data. Bulletin is two-color; contains four pages.

Circle No. 94 on Reply Card

Automatic Precision Tapping

Automatic Methods Inc. — "Auto-Tap", a lead screw tapping attachment which converts any standard 14 to 20-in. drill press into a precision tapping machine and at the same time eliminates the need for a skilled operator, is described in detail in a 4-page bulletin. Order blank and price lists attached.

Circle No. 95 on Reply Card

Automated Sheet Metal Handling

Fried Steel Equipment Mfg. Corp.—A line of strip and materials handling devices for automating sheet metal plants and warehouses includes a Stripveyor to pick up and carry strips beyond shear bed as fast as they are sheared, a Strip-Stacker to stack and store the strip, a Liftveyor to support sheet being cut to tolerances as close as 0.005-in. and to counteract flexing. Eight-page bulletin illustrates and describes three basic machines fully, includes brief summary of an auxiliary scrap eliminator and beltveyor for short shearings.

Circle No. 96 on Reply Card

Auto-Typist

American Automatic Typewriter Co. Pneumatically powered machine, which operates both manual and electric typewriters automatically is the subject of this 6-page bulletin. Auto-typist operates 2½ times faster than human fingers by means of recording precomposed letters or paragraphs on a roll. Operator can select appropriate rolls, and insert personal data manually at any time.

Circle No. 97 on Reply Card

ElectroniK Null Indicator

Minneapolis-Honeywell Regulator Co.—ElectroniK null-balance detector is unaffected by vibration and requires no special mounting or leveling, eliminating disadvantages of conventional suspension galvanometers. Specifications and performance, said to be fastest possible for resistance, and potential measurement with null-balance indicators, are outlined on data sheet 10.0-12.

Circle No. 98 on Reply Card

Design of Special Purpose Devices

Ram Meter, Inc.—Company specializing in design and manufacture of electrical, electromechanical, and electronic devices has published a 16-page illustrative bulletin setting forth a few of the special purpose items produced for specific clients. These include a "sun" motor which operates on solar energy, remote control systems, thermoswitches, instrument shunts, and accelerometers.

Circle No. 99 on Reply Card

Medium Pressure Packaged Boilers

Wm. Bros. Boiler & Mfg. Co.—Three models of packaged steam boilers, meeting steam requirements in the medium pressure range from 4100 to 30,000 lb steam per hour, are described and illustrated in 8-page bulletin. Units burn gas or oil, or combination of both. Operating data and specifications on each model included.

Circle No. 100 on Reply Card

Power and Speed Control Combination

Dynamatic Div., Eaton Mfg. Co.—Fractional horsepower Adjusto-Spede drives are a combination of ac constant speed induction motors, eddy current couplings, and electronic speed control. Units, engineered to meet specific needs of fractional horsepower drives, are said to have wide speed range, accurate control, low power loss, simple and self-contained construction, and rapid response. Eight-page bulletin covers fundamentals of operation, capacity of available units, mechanical construction features, and control.

Circle No. 101 on Reply Card

Silicon Transistors

Texas Instruments Inc.—Descriptive data sheets present mechanical and electrical data, and operating conditions for a medium power and two general purpose silicon transistors. Silicon models are said to offer higher power output and be more independent of ambient temperatures than germanium counterparts. New transistors operate up to 150° C with current amplification essentially independent of temperature change.

Circle No. 102 on Reply Card

Rotary Tables for Indexing, Milling

W. B. Knight Machinery Co.—Power feed rotary tables suitable for rotary milling and indexing, automatic cycle milling and indexing, and continuous face milling have infinitely variable feed drive controlled by limit switches. Eight-page bulletin illustrates and describes the two models, a 20-in. table and a 42-in. version which can be increased to 72-in. diameter with the use of subplates. Sectional views, diagrams, and specifications included.

Circle No. 103 on Reply Card

Knu-Vise Products

Lapeer Manufacturing Co. Complete line of Knu-Vise products such as clamps, pliers and wrenches are outlined in this 26-page bulletin. Air-operated automatic clamps with toggle-bar forces up to a ton of pressure are covered. Clamps are designed for single installations, multiple installations controlled by a single valve, and multiple installations with sequence valve. Bulletin includes specifications, price list and pictures of models.

Circle No. 104 on Reply Card

Industrial Conveyors

Conveyor Systems, Inc.—Informative 64-page booklet is actually a condensed set of data sheets and illustrations demonstrating applications of various conveyor systems. All types of materials handling equipment are covered including trolley, roller, slat, chain, belt and special apparatus. Overhead, underground, inclined, and turning conveyors with all types of carriers illustrated.

Circle No. 105 on Reply Card

Automatic Boilers for Hospitals

Orr & Sembower, Inc.—Two types of automatically controlled, packaged boilers for hospital applications are described in a 4-page bulletin. Boilers are available in 17 sizes from 15 to 500 hp for steam processing, and steam and hot water heating. Typical installations illustrated.

Circle No. 106 on Reply Card

Vibrating Conveyors

Hewitt-Robins Inc.—Well illustrated booklet describes a line of vibrating conveyors that will handle hot or cold, wet or dry, pulverized or lump, packaged or loose materials. Running on relatively low horsepower, these units remain constant under heavy fluctuating loads, level out batch feeds, can be installed as double deckers with top level used as work table.

Circle No. 107 on Reply Card

Presses for Reinforced Plastics

Hydraulic Press Mfg. Co.—An 8-page reference catalog is tabbed for easy filing, covers a series of automatic presses in 100, 150, and 200 ton sizes for reinforced plastics products. Material is plastic reinforced with glass fibers, and products include aircraft parts, electrical flat sheet, and air conditioning housings. Automatic controls are supplemented with pushbutton controls for semiautomatic operation.

Circle No. 108 on Reply Card

Heavy Duty Limit Switch

E. B. Denison Mfg. Co.—Long lasting switch has "bounce" characteristics of a light duty switch and vibration resistance of a heavy duty switch. Single pole, double throw, double break switch has trigger type actuator, is said to be the most easily maintained switch on the market. Complete specifications and cutaway illustrations shown in a 4-page bulletin.

Circle No. 109 on Reply Card

Tests for Lubricating Oils

Crippin & Erlich Labs, Inc. This four-page bulletin lists test for fuels, coal, tars, asphalts, petroleum and oils which are used to lubricate and power automatic equipment. More than 60 tests are included in the bulletin.

Circle No. 110 on Reply Card

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Electrical Panel Instruments

DeJur-Amsco Corp. — Available in round, square, and rectangular models, a line of standard range electrical indicating instruments is specifically designed to meet ASA requirements. Four-page bulletin gives details and illustrates various models of these panel instruments.

Circle No. 111 on Reply Card

Infrared Process Stream Analysis

Perkin-Elmer Corp. — An infrared process stream analyzer can be used in the plant or field for most gas and some liquid analyses which lend themselves to solution by laboratory infrared spectrometers. Analyzer is basically an automatic recording, triple-beam, non dispersion plant instrument utilizing a servo driven attenuator comb in the third beam to produce a true radiation null at the detector. Six-page illustrated bulletin describes operation, specifications, and typical applications.

Circle No. 112 on Reply Card

Monitor and Control Instruments

Consolidated Engineering Corp.—Electronic instrumentation is applied to petroleum, chemical, and medical uses, pressurized and vacuum product testing, and continuous, automatic monitoring and control of gas or liquid flow lines for evaluation of products and processes. Catalog enumerates case histories for various industries with good illustrations in 22 pages, and includes descriptive data on company's control and test instruments.

Circle No. 113 on Reply Card

Dynamic Pressure Measurement

Statham Laboratories, Inc.—The 27th issue of *Instrument Notes*, a series of design data summaries in the physical measurement field, is available to those interested in evaluating the design of transducers for the measurement of dynamic pressures in liquid systems. Eight-page study points out principal factors influencing the selection of unbonded strain wire transducers for measuring dynamic pressures in liquid systems, and presents calculated and experimental data demonstrating effect of varying some of the design parameters of pressure transducers. Author evolves a simple method for predicting the natural frequency and damping ratio of a liquid-filled tube plus transducer system by means of a small-bore, graduated glass capillary tube and a source of known pressures.

Circle No. 114 on Reply Card

Power Spray Washers

Peters-Dalton Inc. — Spray washers, designed for use in metal-working industry are the subject of this 15-page bulletin. Washers can be used on television tubes, heavy machined parts, rotary shells, meat hooks, helical drums and numerous other types of equipment. Layouts and applications, along with 15 engineering drawings of most commonly used washers are included.

Circle No. 115 on Reply Card

General Purpose 2-Way Valve

Automatic Switch Co.—Pertinent data on 2-way, internal pilot operated, solenoid valves is set forth in a 4-page bulletin. Valves control flow of air, gas, water, light oil, and other noncorrosive fluids, and can be applied to instrumentation, machine tools, and appliances. Dimensional diagrams, flow charts, and list prices included.

Circle No. 116 on Reply Card

Automatic Filling Machines

Perl Machine Manufacturing Co.—Four-page circular describes four different fully automatic Perl filling machines. Model "100" does straight line bottle and can filling; model "105" has output of 30 one-gallon cans per minute with eight valves. Features and pictures of machines are given.

Circle No. 117 on Reply Card

Air Data Computer

Servomechanisms, Inc.—Assembly of plug-in components, with associated transducers, provides input information required by the computers and controls governing operation of an aircraft and its armament. Eight-page brochure describes how computer measures and converts to electrical signals fundamental input data which defines environment and operation of aircraft, and then uses signals through servos to produce functions of input parameters in the required form. Schematic diagrams are included.

Circle No. 118 on Reply Card

Pull-Up Broaching Machines

Colonial Broach Co.—Entire line of company's pull-up broaching machines, with capacities of 6 to 50 tons and strokes of 42 to 72-in., is described in a 4-page bulletin. Blueprint, dimensional chart, and specification table supplement text. Machines can be adapted to automatic operation by installation of automatic loading and unloading and transfer devices, or can interlock with other machines in a line type operation. Recent improvements are new electrical and hydraulic control panels, redesigned cooling system, and multiple oil filter section for quick filter replaceability.

Circle No. 119 on Reply Card

DC Indicating Amplifier

Doelcam Corp.—Data sheet gives engineering data, performance curves, and typical applications of a new dc indicating amplifier. Unit is designed primarily as a polarity-sensing microvoltmeter for direct measurement of low level dc signals, for amplification to provide flat response to greater than 20 cycles per second to drive commercial pen motor or galvanometer recorders.

Circle No. 120 on Reply Card

Hand Controlled, Rotary Action Valve

Ross Operating Valve Co.—Rotary handle action or "Pancake" valve is subject of a 4-page illustrated bulletin. This is a 4-way valve, 2-in. high, with poppet type seals and bottom ported base plate to permit removal of body without disturbing piping. Installation data, specifications, and diagrammatic views included.

Circle No. 121 on Reply Card

Climate Survey Temperature Indicator

Beckman & Whitley, Inc.—Data sheet describes a climate survey temperature indicator and its accessory shields. Indicator is a sensitive, rapid responding instrument which is produced in various models to provide a span of 130° F in six overlapping ranges or a single span of 30° F. Basic model is illustrated and described with specifications. An aspirated type psychrometer is available for wet and dry bulb temperature measurements, or for dry bulb, free air temperature measurements. Aircraft type accessory shield permits thermistor units to be mounted on wing tips for meteorological inversion temperature measurements.

Circle No. 122 on Reply Card

Power Transmission Gears, Reducers

Cone-Drive Gears Div., Michigan Tool Co.—"Standardized 7 Ways To Cut Your Power Transmission Costs" is a 4-page bulletin describing standardized reducers and their components, which are interchangeable between units of the same center distance. The seven cost-cutters are the reducers, fan cooling attachments, bearings, gear sets, mountings, shafts, and couplings. Descriptions include hp ratings, reductions, and pinion speeds.

Circle No. 123 on Reply Card

Data Handling by Punched Cards

Remington Rand Inc.—Multi-control reproducing punch uses punched card procedure for descriptions, analyses and breakdowns, extending and computing, searching and sorting, verifying, comparing, correcting, reproducing and interfiling data. Six-page bulletin illustrates procedure, which will handle 6000 to 12,000 cards per hour, and recommends it for production control, payroll and tax accounting, billing, and statistics preparation.

Circle No. 124 on Reply Card

Contract Tooling for Industry

Mechaneers Inc.—Booklet is available on company's package tooling program for industrial clients. Case histories cited include an electric switch company requiring a fast automatic testing machine but with inadequate tooling and development facilities of their own. Service company's program starts with consultation on product blueprint and carries through to actual production without exceeding predetermined cost or delivery date.

Circle No. 125 on Reply Card

Magnetic Particle Clutches, Brakes

Vickers Electric Div., Sperry Corp.—Four-page bulletin describes "Magneclutch" and "Magnebrake" line which operates on a magnetic particle principle. Clutch transmits torque through the magnetic medium to provide smooth acceleration, may be operated manually, by adjustable resistor, potentiometer, or automatic control. Gears, sprockets, linings, pressures, and other mechanical clutching devices are eliminated. Magnebrake provides preset or adjustable braking, from full speed to standstill, without grab or friction wear. Suggested applications include conveyors, dynamometers, automatic lathes, pumps, separators, and vibrators.

Circle No. 126 on Reply Card

Oxygen-Free Atmosphere

Arnold O. Beckman, Inc.—Accurate instrumentation and process regulation provide inert, oxygen-free gases to heat treating, welding, sintering and coating of metals. Bulletin listing and describing necessary equipment is titled "Atmosphere Furnaces".

Circle No. 127 on Reply Card

Chlorinator Automatic Proportioner

Fischer & Porter Co.—Proportioning unit automatically feeds chlorine to water or sewage line in direct and preset proportion to main flow rate. No manual reset is required when main line flow rates change as proportioner varies chlorine flow accordingly. Data sheet contains flow diagram, cross-section drawing, installation drawing, and specifications.

Circle No. 128 on Reply Card

Hydraulic-Pneumatic Testing Panels

Industrial Engineering Corp.—A line of test stands and panels for analysis of hydraulic-pneumatic flow rates, timing, calibration, and leak detection in valves, servos, motors, etc., features built-on flow diagrams so that operating instructions are in full view. Stands handle fluid testing at static pressures up to 50,000 psig or flow rates up to 150 gpm. Six-page bulletin offers complete description plus information on company's gage guard, a protective pressure cutoff control.

Circle No. 129 on Reply Card

Computer Analysis of Instruments

Beckman Instruments, Inc. — "Computer Techniques in the Instrumentation Industries" is a 5-page bulletin covering use of analog computer in design and control problems of instrumentation. An explanation of techniques involved in dynamic analysis of an instrument in use with its associated equipment shows simulation of process control systems and use of analog computer. Galvanometer and process control simulation and an analysis of a motor controller are demonstrated.

Circle No. 130 on Reply Card

AUTOMATION

ABSTRACTS

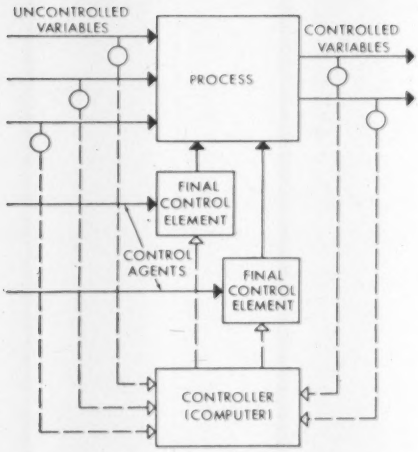

Fig. 1—Block diagram of a multi-element control system

MECHANICAL COMPUTING ELEMENTS

A. PIATT
Librascope, Inc.
Glendale, Calif.

AS INDUSTRIAL PROCESSES become more complex, and better performance is expected, simple control systems may become inadequate. Information may be required about variables which it is not practical to measure directly, but which must be computed from other quantities more easily measured. It is because of such trends in the requirements for automatic control that computing instruments and controllers are becoming increasingly important.

Computations may be performed in a number of ways. The computers may utilize mechanical, electromechanical, or electrical computing elements. This paper will be limited to the consideration of mechanical computing elements which employ rotations or displacements as inputs and outputs.

Open and Closed Loops

Applications of computing devices to the automatic control of industrial processes can be grouped into two broad classifications, open-loop systems, and closed-loop systems.

In open-loop computing systems inputs to the computer result in one or more outputs which have no influence on the inputs. Output information may be in a more useful form than the measured variables, or the output information may be required in addition to the measured variables. Computing and integrating flow meters and ratio computers are examples of open-loop computers which may be used in industrial control. It is apparent that the accuracy of the output for this type of computer depends entirely on the accuracy of the input information and the accuracy of the computation.

In a closed-loop computing system one or more of the outputs is employed to adjust certain control agents in the controlled process. Inputs to the computer are responsive to changes in the variables of the process which in turn are influenced by the outputs of the computer system. Thus, as seen in *Fig.* 1, the system, including the process and computer, is a closed loop which is influenced by changes in the uncontrolled variables of the process.

When there is more than one measured variable and possibly more than one control agent, the system is called a multielement control system and the controller generally will perform certain computations. In multielement control the variables of the process are measured and their effects on the process simulated in the computer so that a change in any of the variables of the process will result in controlling action which tends to maintain the controlled variable at the desired value. Multielement control reduces lags in the process, reduces the effect of changes in uncontrolled variables, and permits closer control of the controlled variable without instability in the system.

Number of inputs employed, and the accuracy of the computer depend on the quality of control desired. For many systems a very simple system using an approximate computer may be employed. In other systems requirements may justify the use of more inputs to the computer and a computer which closely simulates the controlled process. In a closed-loop system the accuracy of the computation may be poor as compared to the precision of control of the controlled variable. The accuracy of all the inputs, except for the controlled variables, also may be of a low order.

Analog Elements

An analog-computing element simulates a corresponding mathematical operation. In some cases an analog-computing element simulates a complete problem or a part of a problem rather than a single mathematical operation. Mechanical analog-computing elements have mechanical inputs and outputs.

Since the mechanical computing components considered here receive inputs as rotations or displacements, manual inputs to such computers can be accomplished conveniently by knobs or handcranks with the functions displayed on dials or mechanical counters. Electrical inputs to mechanical computers require the use of servomechanisms to convert the

electrical quantities to mechanical rotations or displacements. Quantities in a mechanical analog computer are transmitted between computing components by means of shafts and gears for rotations and by means of links for displacements.

Outputs from mechanical computers in some cases can be used directly. The outputs can position dials and counters directly. If electrical outputs are required, transducers such as potentiometers can be driven directly by the mechanical computing components. If considerable power is required from the outputs, servomechanisms or other power-amplification means are required since the power output of the computing components, being moderately small in size, is limited. In the following paragraphs some mechanical analog-computing elements are described which are particularly applicable for use in computing systems used in the control of industrial processes.

Arithmetic

Addition or subtraction is accomplished with mechanical gear differentials when the quantities are available as shaft rotations. When the addition or subtraction is to be performed with displacements rather than rotations, an additive or subtractive link may be used. *Fig.* 2 shows such a linkage. The bar to which the input and output links are connected is the additive or subtractive link. The two outer links are the inputs, and the link in between is the output which represents the sum or difference of the two input quantities. When the distances between the connection point of the output link and the connection points of each of the input links are the same, the output link will move one-half the distance that one input link is displaced when the other input is fixed. By making the two arms of the additive link unequal, the two inputs, in effect, can be multiplied by different constants.

It is seen that by means of linkages such as the additive or subtractive linkage, displacements can be multiplied by constants. For a quantity which is in the form of a shaft rotation, gear ratios are used to multiply the quantity by a constant. If two variables are to be multiplied, a multiplying mechanism is used for mechanical analog multiplication. A linkage-multiplying mechanism is shown in *Fig.* 3. In this multiplying mechanism, the inputs and the outputs are displacements. The two inputs are displaced proportional to the two quantities to be multiplied. The displacement of the output link is then proportional to the product of the two inputs. The inputs and the output, in effect, can be multiplied by constants by the placement of the pivot points for the input and output links. Alignment holes are provided in the mechanism to facilitate setting the zero positions of the inputs and the output.

Integration

When it is desired to perform integration rather than multiplication, or to multiply a shaft rotational speed by a variable, a ball-and-disk integrator may be used. *Fig.* 4 is a cutaway view of a ball-and-disk integrator. The disk is rotated by one input. In integrating ydx, the disk is rotated such that increments of disk rotation are proportional to increments of dx. The ball carriage is displaced proportionally to y. The cylinder or roller is the output of the integrator and the cylinder rotation is then proportional to the integral of y with respect to x. The ball carriage contains a sleeve in which there are two steel balls. The two balls separate the cylinder and the disk which are forced toward each other by a spring in the disk bearing assembly. At the zero position of the ball carriage, the balls are over the center of the disk, and rotation of the disk causes no rotation of the cylinder. The use of two balls in this type of integrator permits positioning of the ball carriage without the balls slipping on either the disk or cylinder, even though there is no rotation of the disk. It is seen that when the ball carriage is moved, the two balls will rotate in opposite directions and will roll against the cylinder and the disk and against each other. For maximum resistance to wear, the disk surface is of Carboloy, which is lapped to a mirror finish.

Generation of Functions

In addition to the mathematical operations mentioned, it is often required to generate functions of one variable. Typical of such functions are exponential, logarithmic, square, square-root, and trigonometric functions. Function generators may be designed for empirical

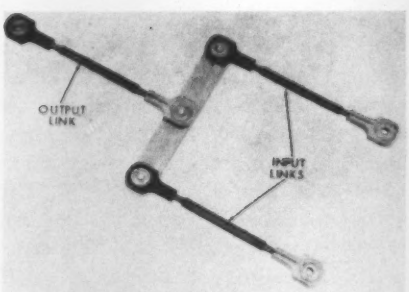

Fig. 2—Additive or subtractive linkage

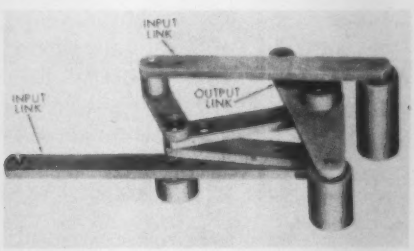

Fig. 3 — Linkage multiplying mechanism

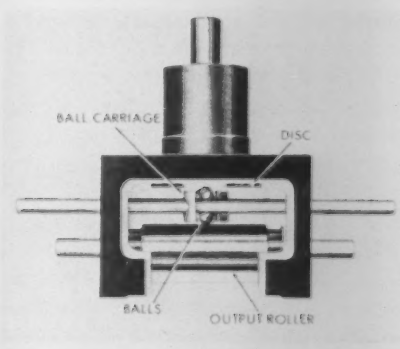

Fig. 4—Cutaway view of ball and disk integrator

relations or intricate mathematical functions. A common type of mechanical function generator is a cam with a cam follower. *Fig.* 5 shows an example of a simple linkage-type function generator. Function generators of this type can be made to approximate quite closely the mathematical functions mentioned. Linkage-type function generators usually require some time to design, but are simple to manufacture.

No attempt has been made to compare mechanical computing with corresponding electrical, electromechanical or digital systems. The form in which inputs are available and the form required for the outputs is probably the most important factor in selecting the type of computation. Speed of computation of mechanical or electromechanical systems is probably adequate for most industrial processes. Little in the way of general statements can be said regarding the preference of one method of computation over another. Each problem should be considered individually to determine which method is most advantageous. It can be expected that the various types of computing devices available will continue to find increased application in the control of industrial processes.

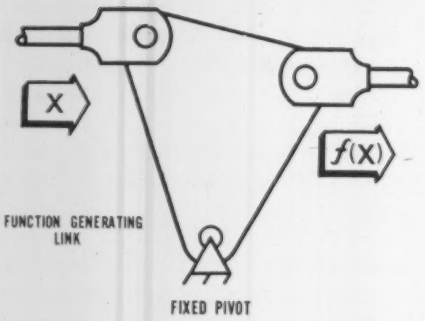

Fig. 5—Linkage type function generator

From a paper entitled "Mechanical Analog Computing Elements and Their Application to Automatic Control" presented at the Annual Meeting of ASME in New York, Nov.-Dec. 1953.

FEEDBACK IN MACHINE CONTROL

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AUTOMATIC CONTROL and specifically feedback control are thought of as recent developments limited to machines—a means by which powerful mechanical tools are directed by a low energy command signal inserted by pushbutton, dial, handwheel, or other automatic devices. Use of automatic control and feedback is actually much broader and almost ageless. The automatic control system serves to maintain body temperature despite wide excursions of environmental temperature level from minus 50 degrees to plus 130 degrees.

Similarly, a machine and control apparatus exist in a changing environment, yet must accomplish useful work both accurately and economically in spite of external disturbances, much as the human being must go about his daily activity, despite summer heat and winter cold. The principles of feedback are applied to machine control to overcome the undesirable effects of vibrations, nonlinear loading, changes in temperature and humidity, and deterioration of the machine itself.

A basic control system without feedback can be built up of three component assemblies, the command, the controller, and the machine. The command element is usually a pushbutton, handwheel, template or more elaborate card, tape, or film programming device, and produces a low energy level command signal analogous to the useful work to be accomplished by the machine. The controller element consists of an amplification device that draws from an energy source to raise the power level of the command signal, and a drive mechanism or motor that responds to the amplified command signal. The drive motors move machine slides and tools to perform actual work fashioned after the magnitude and direction of the command signal.

Fidelity of reproduction from command to actual work depends on the maintained accurate calibration of each mechanical, electrical, hydraulic, and pneumatic components of the command, controller, and machine. The system is susceptible to miscalibration, and deterioration due to random vibrations from an overhead crane or passing tote truck, from simple wear and tear, from changes in temperature and humidity, yet possesses no means of recognizing or correcting errors entering between command signal and the actual work.

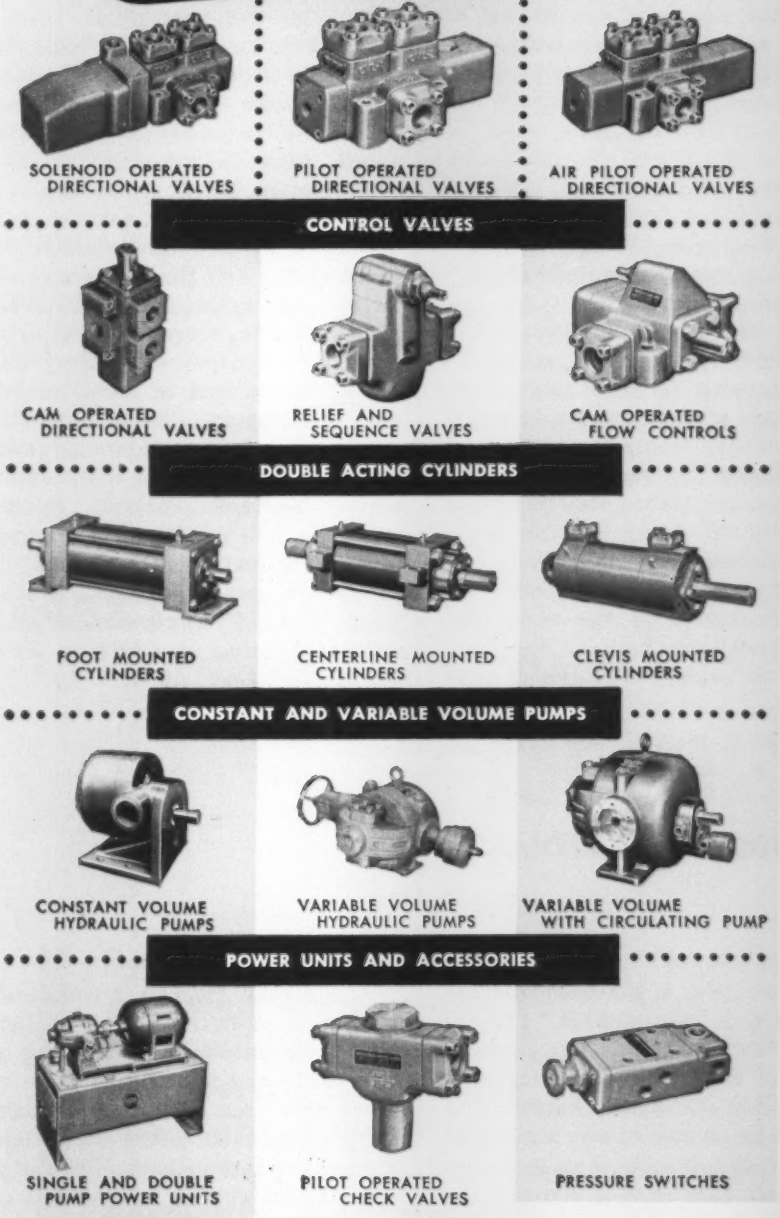
Feedback Control

Resultant poor machine performance can be improved if a measure of the magnitude and rate of change of the actual machine motion is fed back or returned to the controller, compared with the command signal, and the difference used to adjust the machine until the error is reduced within tolerance. When modified in this manner the control system has feedback; it acts continuously to recognize error and to reduce error, whether the error originates within the control components or is caused by external disturbances.

Advantages of the feedback control system over the open or nonfeedback system lie in the ability of the former to force a machine to follow, at a predictable rate and predictable accuracy, a varying input command, and to correct for the effect of changes in environment and the control components themselves without human attention.

In designing a feedback control loop, the objective is to provide accurate regulation of the machine position and motion and rapid recovery following any disturbance, with a minimum of oscillation about the desired output level. The term accuracy is used in several ways. Customarily, the feedback control designer concerns himself with relative accuracy, a measure of how closely the output machine drives follow both fixed and varying input commands. The static

A REALISTIC APPROACH TO THE AUTOMATION TREND



Consider hydraulics for the power and control of your automatic equipment and rely on H-P-M as your best source for hydraulic components. Our complete line of cylinders, valves and power equipment will simplify your planning; our engineering staff and field representatives provide a background of experience that helps solve problems.

The hydraulic components illustrated are only part of the wide selection of standard hydraulic equipment available from H-P-M. Whether your automatic cycle involves mechanical, electrical, hydraulic, air or pressure control sequencing, you'll find the right equipment in the H-P-M line.

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Dept. B

HPM

HYDRAULIC POWER DIVISION

THE HYDRAULIC PRESS MFG. CO.

MOUNT GILEAD, OHIO, U. S. A.

accuracy is largely determined by loop gain—the amplification contained within the total feedback loop when the system is at rest. Increasing loop gain will decrease error and increase static accuracy.

It is important that feedback control system be stable, that is, follow changes in the command without breaking into intolerable oscillations. The concept of feedback implies a comparison between the command signal and actual output that yields a difference or error signal by subtraction. The output member of a stable system may hunt or oscillate about its zero point before coming to rest. If the output is a cutting tool, the work may be gouged or the finish damaged. It becomes important to supply proper damping to bring the output member to rest quickly. However, excessive damping will cause the system to be sluggish and incapable of following rapid changes in the input command. Again a compromise must be made; the proper damping is largely dictated by the input command and output performance specifications of the system.

Without feedback, control accuracy is dependent upon the maintained true calibration of each component. A 10 per cent change in sensitivity of an amplifier may change control accuracy 10 per cent. If, however, the identical deteriorated amplifier were contained in a feedback system, the overall loss of accuracy might well be only a small fraction of one per cent, depending on system gain.

Design and application of programming equipment to command automatic feedback controls is gaining acceptance in general machine control. Punched cards, paper tape, movie film, or magnetic tape on which is recorded consecutive machine position and feedback instructions supply command information without human attention to feedback control loops to perform useful work.

Machine Applications

Information is fed into the programming command unit in continuous or discrete form. At the NACA Lewis Flight Propulsion Laboratory in Cleveland, magnetic tape carrying 60 and 1000 cycle modulated signals directs, through two feedback controls, milling of experimental turbine blades. Alternately, the blades may be milled according to punched card data, which defines each blade cross-section by 25 discrete data points. A small computer in the command unit interpolates between the data points to supply continuous machine instructions. The magnetic tape method enables faster milling; however, punched cards are more easily altered to accommodate design changes.

The preparation time of tape or cards is minimized by construction of a computer integral with the machine and capable of interpolating between a few data points. Examples are the punched tape milling machine control developed at the MIT Servomechanisms Laboratory, and the cam generating control under development at Ultrasonic Corp. On the other hand, it is feasible to divorce the interpolating computer from the machine and use a larger volume of data points, each an increment of machine motion, as illustrated by the movie-film controlled gear shaper developed by Dr. Cunningham of Arma Corp., and the University of Texas cam milling control. The principal advantage of this approach is control simplicity, obtained at the cost of more laborious preparation. Each potential application of a programming command, in conjunction with automatic feedback control, merits economic balance between control investment and operating costs.

From a paper entitled, "Automatic Control" presented at the Annual Meeting of ASME in New York, Nov.-Dec., 1953.

TWO SIDES TO AUTOMATION

K. R. GEISER
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WHAT is automation? This is one of the words most often heard in industry today. What it is, what it will mean to production, to workers, to jobs, to investors, to the public are matters potentially affecting everyone. The word automation is relatively new, but the mechanisms, technology, etc., to which it refers are not something brand new, but merely a new aspect of something long familiar. This is a natural evolution of American mechanical genius and has been "in development" for more than a century.

I would like to start right off and give you a clear-cut concise definition of "Automation." I would like to say that it is the accomplishment of a job by an integrated mechanism and with a minimum of human assistance of any kind. This is very good, it sums it up well; but I am not sure that it conveys the complete picture. And the reason is, as I just said, that the field is developing so rapidly and so many people have ideas concerning it, that it is impossible to get sufficient agreement to call—in all fairness—anything a definition.

Therefore, the best we can do is to call these words I am going to put together "working concepts" instead of definitions. It is a fact that the people who are working in this field are beginning to come to some agreement, but they certainly are not talking the same language yet. An analysis of the situation indicates that—regardless of the absolute meaning of the word—it has assumed two connotations and, while these appear to be definitely related, they do differ in degree, complexity and time of application. It may be that one is an evolution or long range extension of the other.

However, for our purpose, I have

concluded that the confusion can only be removed from the scene by discussing these two concepts separately. An additional reason for this approach is that the first concept will undoubtedly have the most direct effect on your factories and pocketbook during the next few years. Therefore it holds the most interest for you. Also, this concept is not nearly so beclouded by new and strange words. I am going to call the first concept continuous automatic production. The second concept I am going to call the technological concept, because it actually is more concerned with the application of scientific knowledge to the fields of business, industry and manufacturing.

Continuous Flow

Manufacturing people, specifically those of the metalworking industry, have pretty well agreed that to them automation is simply a way of manufacturing. It differs from the old way in that it is a continuous flow concept rather than a batch concept. In the old way, we turned 250 pieces on a lathe and put them in a tote box. Then some time later somehow the tote box was moved to the grinder, where we ground 250 pieces.

This process could be made a continuous flow if the lathe and the grinder were automatic, and we added some automatic transport equipment to remove the piece from the lathe and carry it to and place it in the grinder: with appropriate timing, of course. Here are two automatic machines connected by a small conveyor, but note the overall operation of fabricating is now continuous instead of in batches. Also note that the man who moved the tote box from one machine to the other has now been relieved to do more useful work.

This is not complicated! I am sure that you can visualize such an addition to your own factory. In other words automation is continuous automatic production. This interpretation is not narrow, but covers the automatic making, inspecting, assemblying, testing and packaging of parts and products in one continuous flow. So the continuous automatic production concept says that automation is a way of manufacturing characterized by the combining of automatic machines with transfer or handling equipment, which handling equipment moves the parts into and out of load and unload stations of the machine tools. It may, of course, be necessary that this handling equipment index, position, turn or rotate the parts so as to line them up for succeeding operations. This in-process material handling is not restricted to handling just large parts, but can be used for castings, forgings, stampings, etc.

Closed Loop Control

A new science has come into the picture and with it comes a better understanding than we have ever had before of our communication and information handling problems. All of this gives us attractive food for thought. Any one of these intriguing new knowledges—computers, feedback or what have you—is

NEXT MONTH IN

Design For Manufacture . . . . *R. W. Bolz*
Applying Bottle Seals . . . . *(Pictorial)* . . . Automation Today
Hydraulic & Pneumatic Servos . . . .Part 2 . . . . *R. Hadekel*
Engineering Automation Systems . . . . *Philip R. Marvin*
Pneumatic Time Delay
Latex to Foam Rubber Automatically . . . . *Leonard J. Bishop*
Automatic Control Terminology . . . . Part 4
Pneumatic Control Paint Sprayer . . . . *Donald J. Peeps*
Electronic Servo Positioning . . . . *Walton Rainey*
Continuous Weighing of Solids . . . . *Robert H. Berg*

And many more idea-packed articles! For complete index of articles which have appeared so far in Automation, see page 106

not sufficient in itself—it is merely a means to an end. These things bear on and augment each other and begin to form a pattern, and the pattern fits together so very well that it is apparent that it will have a profound effect on our future.

This is the important factor—it is no single machine or component or science—but the bringing together and integrating of knowledge and know-how from many places that results in a tool more powerful than any one device or science by itself could ever achieve. This combining—this bringing together of knowledge—may not only be the key to the factory of the future, but it may be the key to all progress of the future.

This technological concept is perhaps more glamorous and more thought-provoking than the first, and there certainly are those who contend, and perhaps rightly so, that in the long haul, this concept will have the more profound effect and constitute the vital element of automation. However, I have the feeling that most of you are a little more interested in your factory's profit for next year than you are in your factory's glamour.

Earlier, I indicated that these things we are talking about certainly are not brand new. Some of them are very old, others exist already in other forms. For proof that they are not brand new, we need only to look around us and to recall a little of our history. Most of the basic components are already in existence in your factories. You already have many automatic machine tools, and I dare say many of you have some automatic conveyor equipment. Remember these were the components of continuous automatic production.

Even the more elegant components have been with us in understandable form for a long time. The modern "servomechanism," as we know it, existed in principle in 1788 in Watt's fly-ball governor for the steam engine, and its theory was described as early as 1868 by James Clerk Maxwell.

People today are talking about controlling machines from punched cards or punched tapes: the Jacquard loom was exactly this and has existed since 1801. Actually, the fully automatic digital computers which you are reading so much about today were conceived around these Jacquard type punched cards. In 1850, Charles Babbage described to a remarkable degree a completely automatic digital computer as we know it.

And automatic factories are not new. The classic example is Oliver Evans' flour mill built near Philadelphia in 1874. Here grain was processed into flour without benefit of human assistance. If we just stop and think for a minute, we can find some businesses that already today are almost fully automatic.

In many technical fields, man has often been able to look ahead and foresee the necessity for desirable devices or systems. In some cases, he has been able to conceive the theories and visualize the assemblages of equipment which will solve the problem. But only when practical components become available do these dreams become realities. Neither the servomechanism nor the computing machine would be more than a laboratory tool today had it not been for the perfection of the modern techniques of electrical control and amplification, both dependent on the existence of such devices as the vacuum tube, with its simplicity of structure, its low cost and its extreme economy of power.

Man has always devoted much of his effort to finding ways and means to accomplish or circumvent the arduous and laborious tasks, especially those not requiring his full ability as a human being. With the advent of the steam engine and then the electric motor, man greatly improved his industrial efficiency. But even so, there still exist in industry today many tedious, time-consuming, laborious or simple discrimination jobs which often result in mental stagnation to the people who perform them. It does not require the full complexity of the human mind and body to carry tote boxes from one machine to the next nor to load parts in a lathe, nor to tighten bolts and solder wires in building, for instance, automobiles or radios.

As surely as man lives and thinks and strives for a better way of life, these things will be replaced. They are being replaced today.

From a talk entitled "What Is Automation?" given at the Conference on Automation and Industrial Development sponsored by the State of New York in Syracuse, May 1954.

REMOTE WEIGHT MEASUREMENT

J. J. HICKS
The Chemstrand Corp.
Pensacola, Fla.

INCREASED USE of remote centralized control in process industries has emphasized the need for an accurate weight-measuring system which can successfully transmit the weight indication over a distance of several thousand feet. This need, which was responsible for the development of the weighing system to be discussed in this article, is a typical example.

It was required that the weight of the contents of several storage bins, each of 60 tons capacity, be indicated in a central control room 300 yards distant from the point of measurement at the bins in the plant area. The accuracy of the weight measurement should remain unaffected by temperature variations, transmission lag, vibration, corrosion, off-center loading, and windage. Although the initial application required that the signal from the weighing system be capable of providing only an indication or record, the ability to use the weight measurement signal to control the discharge of the material from the storage bins would offer certain advantages in the process operation.

Hydraulic System

System of weighing which has been proposed for this application uses four hydraulic load cells to support each storage bin. The hydraulic chamber at the base of each load cell is connected to a Bourdon tube. Variations in hydraulic pressure created by changes in the weight which a load cell is supporting will cause the tip of the Bourdon tube to move. Attached to the tip of each Bourdon

tube is the armature of a differentially-wound electrical transformer. Motion of the armature within the transformer winding will produce a variation in the voltage output from the transformer. The connections from the four transformers are arranged to provide a single electrical output signal which is indicative of the total weight being applied to the load cells.

Electrical Transmission

This electrical signal is transmitted to a receiving indicator where it appears as an unbalanced signal voltage input to an amplifier. It is amplified and used to actuate one phase of a small servomotor. The motor drives a mechanical linkage to position the armature of a similar differential transformer located in the receiver. This action produces a voltage output from the receiver transformer which nullifies the transmitted weight signal and restores electrical balance to the circuit feeding the amplifier.

With the circuit in electrical balance, there is no further input signal to the amplifier and consequently no further motion from the servomotor. The action of the servomotor in positioning the armature of the receiving transformer also drives the indicator pointer, or recorder pen, to the proper calibration on a scale or chart. The pointer or pen will remain in this position until a change in load in the storage bin again creates a similar cycle of servo action.

For this application it was desired that the weight of the bin contents be indicated locally in the immediate area where the bins are mounted as well as in the remote central control room. This feature was achieved in the system design by locating the receiving indicator described above in the local area, and retransmitting to the remote control room by means of a similar differential transformer operating in tandem with the receiver.

From a paper entitled "Remote Weight Measurement by Means of Hydraulic Load Cells with Electrical Transmitters" presented at the National Instrument Congress sponsored by ASME in Chicago, Sept. 1953.

Digital Computer Techniques

Applied to the design, development and application of

Electronic Business Systems
Military Radar Fire Control Systems
Aircraft Control and Navigation Systems

The successful application of Hughes airborne digital computers to high speed aircraft fire control problems has opened up an entire new area for these digital computer techniques. Similar equipment is now under development in the Advanced Electronics Laboratory to apply such digital computer systems to modern business information handling.

Areas include

LOGICAL DESIGN
COMPONENT DEVELOPMENT
PROGRAMMING
MAGNETIC RECORDING
CIRCUIT DESIGN
INPUT & OUTPUT DEVICES
SYSTEMS ANALYSIS

Hughes *developments in these fields are creating new positions in the Advanced Electronics Laboratory. Exceptional men in the following spheres of endeavor are invited to apply:*

Engineers and Physicists

Computer activities embrace systems planning and analysis, design and development, system engineering and component development. Experience in these areas, as well as in application of electronic digital computers, is desirable but not essential. Analytically inclined men with backgrounds in systems work are required for this phase.

Scientific and Engineering Staff

Hughes

RESEARCH AND DEVELOPMENT LABORATORIES

Culver City, Los Angeles County, California

Assurance is required that relocation of the applicant will not cause disruption of an urgent military project.

AUTOMATION

PATENTS

Copies of patents are available at 25 cents each from the Commissioner of Patents, Washington 25, D. C.

Controls

AUTOMATIC STEERING CONTROL APPARATUS FOR SELF PROPELLED VEHICLES

Rotating drum switch has circumferentially spaced calibrations corresponding to lineal measurements of vehicle travel and engages contact on adjacent lead screw. Limit switches and electric clutches control direction and rotation of drum and lead screw which control electric motor connected to steering apparatus. Patent 2,674,331 by Stanford R. Ovshinsky.

AUTOMATIC LANDING AND LEVELING ELEVATOR SYSTEM

Load responsive control includes: Direct current main generator, driving motor, regulating generator, bridge circuit, and brake mechanism. Applies first braking effort at predetermined distance before predetermined landing; responds to overtravel, retards braking effort, returns to landing, applies stronger braking effort; responds to car movement without motor motion, returns to landing, and applies still stronger braking. Patent 2,674,348 by Danilo Santini, Phillip C. Keiper and Milton Fink, assigned to Westinghouse Electric Corp.

HYDRAULIC ACTUATING AND CONTROL CIRCUIT FOR MACHINE TOOLS

Actuator, pump, accumulator, main control valve, feed rate control valve, and load valve combined in circuit for machine tool control. Patent 2,674,850 by Ernest J. Svenson and Swen H. Stone, assigned to Odin Corp.

CONTROL SYSTEM FOR CONCRETE BLOCK MACHINES

Material filled and compacted by vibration whose time is controlled based on length of vibration cycle and height of material in mold. Patent 2,672,669 by Robert O. Davis, assigned to The Gene Olson Corp.

FLUID FLOOD CONTROL APPARATUS

Uses two containers and capacitance units in electric circuit. Patent 2,672,880 by Harry H. Hermanson, assigned to Minneapolis-Honeywell Regulator Co.

CONTROLLING OR SELECTING MECHANISM FOR INDIVIDUAL SWITCHES

Used with multiswitches of the crossbar type utilizes clutch to actuate the selected switch. Patent 2,672,060 by Martinus den Hertog and Georges Xavier Lens, assigned to International Standard Electric Corp.

BURNER SAFETY CONTROL SYSTEM

Relays, resistors and switches arranged to control electric fuel burner by unheated stack resistor. Patent 2,672,188 by Robert J. Cassidy, assigned to General Motors Corp.

FURNACE CONTROL MEANS

To adjust the gas flow in a hot air system in response to temperatures in the furnace, at the outlet, and in the room. Patent 2,672,291 by William V. Rifle, assigned to Lucson Corp.

COMBINED THERMOSTAT AND AUTOMATIC PILOT CONTROL

Comprising in combination main and auxiliary valves biased toward closed position. Patent 2,672-292 by Michael J. Caparone and Charles M. Vaughn, assigned to Robertshaw-Fulton Controls Co.

ELECTROMECHANICAL CONTROLLING AND COUNTING SYSTEM

Uses electronic pulse triggering circuit and magnetic yokes for controlling angular rotation. Patent 2,672,067 by Erik B. Hansell.

DAMPING SYSTEM FOR ELECTRICAL SERVOMECHANISMS

Servo consisting of transmitter, receiver and transmission line connecting these assemblies each of which includes an adjustable element wherein the lack of position identity develops an error voltage at the receiving assembly. Error voltage operates relay that energizes power means for displacement of receiver assembly adjustable element in a direction to reduce the error voltage. Patent 2,674,707 by Elmer G. De Mott—assigned to Western Electrical Instrument Corp.

♦ ♦ ♦

Handling

OUTSIDE FEEDING MECHANISM POR AUTOMATIC SCREW MACHINES

Attachment consists of trough slideway with chain and sprocket driven pusher controlled by friction clutch on power unit to move stock to spindle. Patent 2,674,799 by Erwin P. Herzog.

METHOD AND APPARATUS FOR SELECTIVE SORTING

Objects of uniform size and shape having large end and small end sorted and delivered in oppositely oriented pairs to a work station. Patent 2,672,630 by Robert E. Bitzer, Wilson E. Manown and Fred W. Loy.

FEEDER FOR FISH CUTTING MACHINES

Orient and feed fish into alternate channels of block type conveyor in a head-first and belly-down position. Patent 2,672,647 by Oscar J. Haber.

SHEET FEEDING MECHANISM

Two section roller feeding device for metal

sheets applies lubricant as it feeds sheets to processing unit. Patent 2,672,835 by Axel Paul, assigned to Radio Steel and Mfg. Co.

FRUIT SIZER

Flat round horizontal plate with square cornered holes equally spaced on its periphery, each having right angle notched base plate that is cam actuated to increase and decrease the effective opening as the plate rotates over separated bins. Patent 2,673,646 by Charles Clifford DeWitt.

BREAD DEPANNER

Loaded bread pans enter on conveyor, invert as they drop off the end onto second conveyor which catches the pan and allows the bread to go through to third conveyor—bread and pans delivered to separate positions. Patent 2,673,652 by Rufus P. Steadman, assigned to Baker-Perkins, Inc.

♦ ♦ ♦

Machines

MACHINE FOR REMOVING INSULATION FROM THE ENDS OF WOUND ARMATURE WIRES

Eight station horizontal dial to load, burn, brush, bend and brush to clean wires preparatory to securing them to commutator segments. Patent 2,671,913 by Carl W. Kirsch assigned to The Hoover Co.

APPARATUS FOR CONDUCTING MOLTEN METAL

Continuous casting of steel a fluid cooled valve consists of a refractory tube separated from its supporting metal shell by loose finely divided refractory material and having a refractory plug supported on the end of the shell. Patent 2,674,019 by Irving Rossi, Rufus Easton, and T. Yates Wilson, assigned to Continuous Metalcast Co.

EXTRUSION MACHINE FOR THE PRODUCTION OF AN INSULATING COVERING OF AN ELECTRICAL CONDUCTOR

Conveyor screws in rotating head extrude and helically wind threads of a thermoplastic material around a wire fed through center of head. Patent 2,674,007 by Ernst Allemann, Ernst Fritschi, and Herbert Leu, assigned to Schweizerische Isola-Werke, Switzerland.

AUTOMATIC HAT BLOCK CHUCK

Mounts hat blocks on hat finishing machine and is operated automatically by same control lever that starts and stops the machine. Patent 2,673,014 by Frederick R. Marindin, assigned to Doran Brothers, Inc.

ARMATURE ASSEMBLING MACHINE

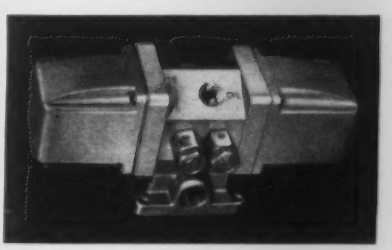
Core discs with notched central opening are aligned and assembled to shaft having longitudinally extending key. Patent 2,673,391 by Richard M. Goodwin, assigned to General Motors Corp.

MACHINE FOR MAKING BARBED WIRE

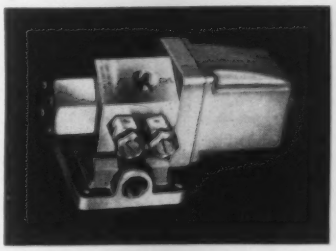
Barb forming head feeds, twists and cuts off barbs around strand forming wires. Patent 2,673,-578 by John B. Getz, assigned to Interlocking Fence Co.

NEW BECKETT "HI-CYCLIC" SOLENOID VALVES

set highest industry standards for performance—long solenoid life—rapid maintenance.



New design improvements in Beckett "Hi-Cyclic" Valves greatly reduce or eliminate the most common causes for solenoid valve downtime. Solenoids are continuous duty, industrially accepted type, practically shock-free mounted for extremely long life. There is no metal-to-metal contact between solenoid and valve piston. Electrical connections are channeled through ½" NPT conduit outlet at the base of the valve. Quick disconnect electrical connectors are employed. Solenoid coil can be quickly removed without dismantling valve or disturbing electrical circuit. Tedious solenoid adjustment is eliminated.



SOLENOID VALVE DATA

These high performance valves are available in six sizes, ⅛" to 1" NPT in single solenoid, spring return, and double solenoid types. For operating on air or other non-corrosive gas (pressure range, 29.9" Hg. VAC. to 150 PSIG.) and oil or water hydraulics (max. pressure 1500 PSI.). Three-way and four-way, two-position and three-position. All common AC and DC voltages. Positive adjustable spring load on single solenoid. Adjustable flow control on air valves. Moisture-tight covers. All materials corrosion resistant. Changes from one model into another can be readily made in the field.

A *COMPLETE* VALVE LINE

"Hi-Cyclic" MECHANICAL VALVES—air and hydraulic—are available in six sizes, ⅛" to 1" NPT, actuated by hand lever, foot lever, fingertip lever, cam roller, piloted; 3-way and 4-way, 2-position and 3-position with detent and spring load to center on 3-position models. Also combinations of actuators.

"Hi-Cyclic" MANIFOLD-MOUNT VALVES—air and hydraulic—available in electrical and mechanical types listed above, in sizes ⅛" to ½" (modified) NPT sizes. *Made for automation*, manifold mounting permits fast replacement of all critical valve parts, including valve body and spool assembly, without disturbing piping, manifold block or electrical circuit.

WRITE FOR COMPLETE VALVE SPECIFICATIONS AND NAME OF NEAREST SUPPLIER

THE BECKETT-HARCUM COMPANY

1093 WAYNE ROAD, WILMINGTON, OHIO

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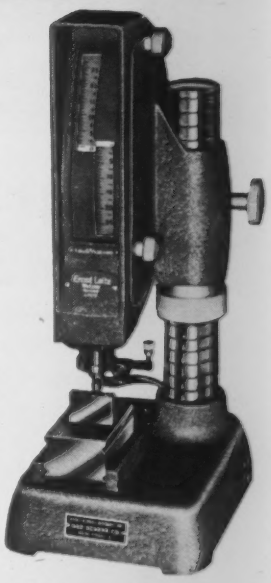

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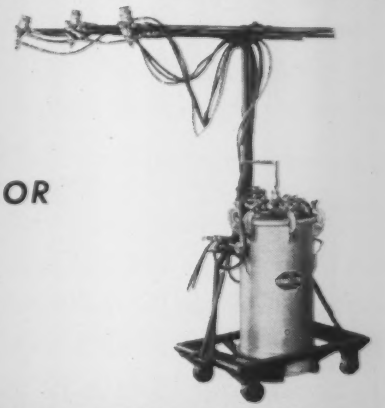

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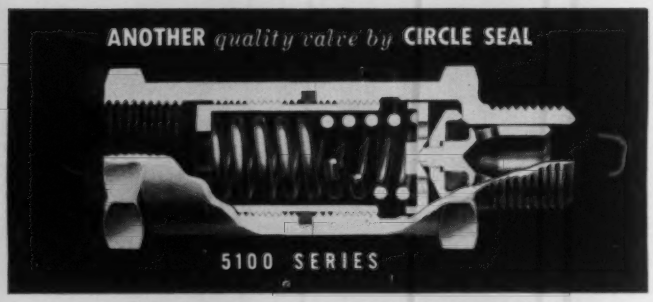

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This comprehensive text emphasizes the fundamental physical principles of measurements, on the reduction of observations and the statistical analysis of errors. Among the subjects covered by the author are: errors and the treatment of experimental results, mechanical design, materials of construction, vacuum technique, electrical measurements, electronics, optics and photography, limits of measurement, and techniques of nuclear physics. The numerous illustrations, charts and tables will aid the reader in planning future experiments of his own.

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AUTOMATIC AND MANUAL CONTROL

By A. Tustin, Professor of Electrical Eng., Birmingham University; 584 pages, 7 x 10 inches, clothbound; published by Academic Press Inc., New York; available from AUTOMATION, *$10.00 postpaid.*

This book consists of the papers read at the conference on Automatic Control organized by the Dept. of Scientific and Industrial Research together with the material presented during discussions. It is beamed, as a work reference, to individuals engaged in the design of control equipment. In addition it serves as a valuable source of information for those having some background knowledge who desire to extend this basic understanding into various and more specialized directions.

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AUTOMATIC DIGITAL CALCULATORS

By A. D. Booth, Birkbeck College, London, and K. H. V. Booth, Birkbeck College, London; 231 pages, 5¼ by 8½ inches, clothbound; published by Academic Press Inc., 125 East 23rd St., New York 10, N. Y.; available from AUTOMATION, *$6.00 postpaid.*

This guide to the theory, design, construction, and use of digital computers discusses various well known computing machines such as Univac and their respective niches in this relatively new field. Overall design of a computing system is broken down to memory and control components, and input and output devices. A large section is devoted to coding, and sample orders and programs are set up. Specific codes for well known machines are outlined.

Study of program design covers the use of tables and interpolation, the storage of tables, and polynomial expansions. Unusual applications of calculators in language translation and as partners in card and chess games, and a theoretical discussion of the "intelligence" and learning capacities of calculating machines complete the volume.

Government Publications

Electrets. *Report PB* 112749 *by Air Force Cambridge Research Center; 116 pages; available from Library of Congress, Publication Board Project, Washington* 25, *D. C.;* $4.75 *per microfilm,* $15.00 *per photostat.*

Basic research on the electrical properties of carnauba wax electrets is covered in terms of possible application of the wax as the sensitive element in electronic equipment and as "memory" device in computing machinery. Electrets are able to reverse their original charges and maintain the high final charge for years. Graphs and tables give discharge currents of various electrets, and experimental techniques are discussed and illustrated.

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Theory, Characteristics, and Applications of Fixed Electronic Capacitors. *Report PB* 111368 *by Wright Air Development Center; 91 pages; available from U. S. Dept. of Commerce, Office of Technical Services, Washington* 25, *D. C.;* $1.25.

Information on fixed capacitors has been compiled for electronics design engineers from books, technical journals, and house organs. Study discusses general capacitor qualities and uses, specific applications to radio receivers, transmitters, and time delay circuits, capacitor inductance, three-terminal and buffer capacitors, dielectric absorption and impregnants. A dictionary of capacitor applications and recommended types is included, as are capacitor formulae and useful constants.

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Breakdown of Potentiometer Winding as a Result of Hipot Testing. *Report PB* 111370 *by Air Force Cambridge Research Center; 14 pages; available from U. S. Dept. of Commerce, Office of Technical Services, Washington* 25, *D. C.;* 50 *cents.*

Report on research in prevention of potentiometer winding breakdown during high-potential production testing presents test methods and results, and theory explaining the phenomenon. Recommendations for preventing breakdown include gradual increases in test voltages and use of enameled wire in winding of resistance elements.

•

A Junction Triode Transistor Experimental Test Set. *Reported PB* 111173 *by Naval Research Laboratory; 11 pages; available from U. S. Dept. of Commerce, Office of Technical Services, Washington* 25, *D. C.;* 50 *cents per copy.*

Report describes a test set which permits rapid determination of approximate electrical characteristics of junction transistors. Set gives reasonably accurate determination of low-frequency internal equivalent parameters of contemporary junction transistors, with accuracy of 5 per cent for normal range of transistor parameters.

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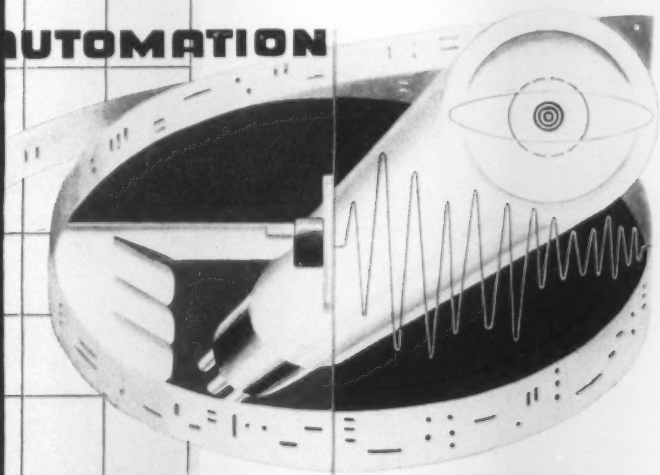

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